Relationships Between Animal Welfare and Economic Outcome at the Farm Level

- *A Quantitative Study of Danish Pig Producers*

Tomasz Gerard Czekaj, Aske Schou Nielsen, Arne Henningsen, Björn Forkman, Mogens Lund

Table of Contents

Preface

This report contains statistical studies of the empirical relationship between animal welfare and economic outcome at the farm level for pig production in Denmark. Herd level data from the inspection of the animal welfare legislation at Danish pig farms in 2010 and 2011 is obtained from the Danish Veterinary and Food Administration and analysed together with accounting data received from the Danish Pig Research Centre in cooperation with the Danish Knowledge Centre for Agriculture. The statistical analyses have been carried out during 2012 and 2013.

We are grateful for receiving the permission to analyse data from the Danish Veterinary and Food Administration as well as from the Danish Pig Research Centre and the Danish Knowledge Centre for Agriculture. The project is financed by the Danish Centre for Animal Welfare under the Danish Veterinary and Food Administration.

The report is written by Tomasz Gerard Czekaj, Aske Schou Nielsen, Arne Henningsen and Mogens Lund, Department of Food and Resource Economics, Faculty of Science, University of Copenhagen and Björn Forkman, Department of Large Animal Sciences, Faculty of Health and Medical Sciences, also University of Copenhagen. The authors have the full responsibility for the content of the report.

Mogens Lund, Projectleader
September 2013

Abstract

This report investigates the empirical relationship between animal welfare and economics among pig producers in Denmark. We apply data from the inspection of the animal welfare legislation at Danish pig farms. While this data is on legislative compliance rather than a direct measure of animal welfare, we assume that it is also of relevance for animal welfare assessments. Based on this data we propose several indicators of animal welfare which are then used in the economic analyses.

The economic analyses consist of three parts. The first part presents results of descriptive analyses where possible correlations between economic variables and the constructed indicators of animal welfare are investigated. The results show that farm size and experience are uncorrelated with animal welfare. Good animal welfare on integrated pig farms is correlated with having higher gross margins per pig unit, despite also having significantly higher medicine and veterinary costs per pig unit. Good animal welfare on specialized slaughter pig farms is correlated with having low medicine and veterinary costs per pig unit. These results indicate that the relationship between animal welfare and the economic outcome of pig producers should be interpreted within the context of the production type.

The second part provides results of regression analyses which generally confirm the relationships found in the descriptive analyses; however the number of identified significant correlations is smaller in the regression analysis than in the descriptive analyses.

In the third part method of econometric analysis of technical efficiency is used to investigate the relationship between animal welfare and technical efficiency of Danish pig producers. Results show that farms with good animal welfare management are on average more technically efficient.

Dansk sammendrag

Projektets formål og baggrund

Projektets overordnede formål er at undersøge om der kan identificeres signifikante sammenhænge mellem overholdelse af lovgivningen på dyrevelfærdsområdet, her brugt som indikator for dyrevelfærd, og økonomi på bedriftsniveau. Den almindelige antagelse er, at højere dyrevelfærd er forbundet med større omkostninger. Imidlertid må det forventes, at sammenhængene mellem dyrevelfærd og økonomi er mere komplekse. Det kan eksempelvis ikke udelukkes, at god dyrevelfærd i besætningen, målt som overholdelse af lovgivningen, er positivt korreleret med de økonomiske resultater som fx størrelsen af dækningsbidraget, idet god (dårlig) management kan øge (mindske) både dyrevelfærd og økonomiske resultater. Projektet analyserer denne og andre hypoteser om sammenhængene mellem dyrevelfærd og økonomi på bedriftsniveau.

Analyser af sammenhængene mellem dyrevelfærd og økonomi kan bidrage med større indsigt i de driftsøkonomiske incitamenter til at sikre en bedre dyrevelfærd i den enkelte besætning. Større viden om de økonomiske incitamenter – og eventuelle barrierer – til øget dyrevelfærd blandt forskellige husdyrproducenter kan også bidrage til øget regelefterlevelse samt en mere målrettet og omkostningseffektiv offentlig regulering af den fremtidige dyrevelfærd.

Endvidere kan sådanne analyser give større indsigt i, hvad en forbedret dyrevelfærd må koste i forskellige situationer uden at det går ud over landbrugets indtjening og konkurrenceevne. Såvel dyrevelfærd som omkostningerne til dyrevelfærd er vigtige konkurrenceparametre. Det gælder ikke mindst svinekød og smågrise, hvor Danmark har en stor eksport.

Der findes i dag ingen systematiseret empirisk viden om, hvorvidt god dyrevelfærd er en økonomisk gevinst eller omkostning i landbruget. Det skyldes blandt andet, at dyrevelfærd er et særdeles sammensat begreb, som er vanskeligt at definere og kvantificere. Øget dyrevelfærd drejer sig ikke kun om at forbedre dyrenes sundhedsstatus, men også om i andre henseender at give dem et bedre liv, fx ved at mindske forekomsten af frustration og frygt, og ved at give dyrene mulighed for at udfolde naturlig adfærd. Landmanden har et klart økonomisk incitament til at sikre dyrenes basale behov og sundhed, i det omfang disse påvirker produktiviteten, men derudover véd vi meget lidt om landmandens motivation og holdninger til at forbedre den samlede dyrevelfærd i sin besætning.

Projektets gennemførelse

Projektets gennemførelse har omfattet fire faser:

- Samkøringafdatabaser

- Beskrivendeanalyser
- Multivariate analyser
- Effektivitetsanalyser

Samkøringafdatabaser

Det anvendte datamateriale bygger på en samkøring af regnskabsdata fra økonomidatabasen på Videncentret for Landbrug i Århus og databaser i Fødevarestyrelsen. De anvendte databaser i Fødevarestyrelsen er dyrevelfærdskontrollen for 2010 og 2011 og den nulpunktsundersøgelse, som blev gennemført i efteråret 2011. (Som tidligere nævnt så bruges overholdelse af lovgivningen som indikator for niveauet af dyrevelfærd i denne studie.) Velfærdskontrollen gennemføres årligt på 5 pct. af alle landbrug med mere end 10 landbrugsdyr eller heste og er baseret på en kombination af risikovurdering og en tilfældig udvælgelse af Fødevarestyrelsen. Nulpunktsundersøgelsen er gennemført som en tilfældig stikprøveundersøgelse blandt alle danske svinebesætninger. I nærværende projekt er derfor udelukkende undersøgt statistiske sammenhænge mellem dyrevelfærd og økonomi i svineproduktionen.
For de bedrifter i velfærdskontrollen og nulpunktsundersøgelsen, hvor der konstateres overtrædelser af velfærdsreglerne, er der oplysninger om arten af overtrædelserne og karakteren af de relaterede påbud, indskærpelser o. lign. Disse oplysninger er blevet suppleret med økonomiske data fra de samme bedrifter for regnskabsåret 2011. De økonomiske data er stillet til rådighed af Videncenter for Svineproduktion i samarbejde med afdelingen for Økonomi på Videncentret for Landbrug i Århus. For hver bedrift er følgende regnskabsmæssige oplysninger blevet modtaget fra Videncentret: Antallet af producerede grise; dækningsbidraget pr. dyreenhed (svin), dyrlægeomkostningerne pr. dyreenhed (svin), landmandens alder, og hans antal år som selvstændig landmand (som proxy for landmandens erfaringer). Endvidere er for hver bedrift modtaget input og output data til de gennemførte effektivitetsanalyser. Disse data er omtalt senere.

Uanset hvilke data, som er til rådighed, vil en præcis definition af dyrevelfærd altid være en vanskelig opgave. Dyrevelfærd er ikke nogen eksakt størrelse. Staldforhold og miljøfaktorers påvirkning af dyrevelfærden kan tolkes på forskellig måde bl.a. afhængig af, hvilke indikatorer for dyrevelfærd der gøres brug af. En litteraturgennemgang viser ingen entydige sammenhænge mellem dyrevelfærd og økonomi, måske fordi de fleste produktionsøkonomiske studier af dyrevelfærd kun benytter et enkelt mål for dyrevelfærd, fx halthed, eller beregner omkostningerne til forskellige produktionssystemer med forskellig velfærd ud fra modelbaserede standarder. Det betyder, at de empiriske sammenhænge mellem dyrevelfærd og produktionsøkonomi fortsat er uklare og dermed ikke videnskabeligt dokumenteret. Et samlet mål for dyrevelfærd kræver principielt et overordner indeks, som inkluderer alle relevante aspekter af dyrevelfærd. Et sådant mål er ikke udarbejdet i nærværende projekt.

I denne undersøgelse er benyttet forskellige indikatorer for dyrevelfærd, som alle kan beregnes ud fra de tilgængelige data i velfærdskontrollen og nulpunktundersøgelsen. Den første indikator er en binær variabel, som angiver hvorvidt der er sket overtrædelser af dyrevelfærdslovgivningen eller ikke, og det uanset antallet og betydningen af de konstaterede overtrædelser. Den anden indikator angiver derimod det totale antal overtrædelser af velfærdslovgivningen og det gælder igen uanset betydningen af overtrædelserne. Den tredje anvendte indikator, som er en kategorisk variabel, angiver den mest alvorlige overtrædelse af dyreværnslovgivningen. Indikatoren siger ikke noget om arten eller antallet af overtrædelser.

Hverken indikatoren for hvorvidt der er sket en overtrædelse, antallet af overtrædelser eller den mest alvorlige overtrædelse siger noget direkte om det konkrete niveau af dyrevelfærd i en besætning. For at analysere en mere direkte sammenhæng til dyrevelfærd, er der tillige lavet indikatorer, som angiver hvorvidt der er observeret overtrædelser af dels dyrevelfærdsreglerne vedr. henholdsvis rode- og beskæftigelsesmateriale, dels reglerne for håndtering af syge dyr.

En aggregering af data har været nødvendig for at beregne indikatorerne for alle de bedrifter, som indgår i analysegrundlaget. Det skyldtes især, at de økonomiske data er opgjort på bedriftsniveau, mens data i velfærdskontrollen og nulpunktsundersøgelsen er opgjort på besætningsniveau. Det giver problemer med aggregeringen af data på de bedrifter med flere besætninger, der hver har sit eget nummer i det Centrale Husdyr Register (CHR).

Det er vigtigt at være opmærksom på, at de anvendte indikatorer alle er meget simple, og at de ikke nødvendigvis afspejler den samlede dyrevelfærd i den enkelte besætning.

Statistiske analyser viser, at data fra henholdsvis velfærdskontrollen og nulpunktsundersøgelsen på visse områder er signifikant forskellige. Antallet af kontrollererede besætninger per bedrift er forskellige i de to undersøgelser, men antallet af kontrollerede besætninger per bedrift har ingen indflydelse på størrelsen af de valgte indikatorer for dyrevelfærd. Det indikerer, at den valgte metode til aggregering af dyrevelfærddata fra besætnings- til bedriftsniveau ikke har ført til signifikante skævheder i analyserne. Derimod er den relative fordeling af bedrifter i forhold til driftsformen forskellige i velfærdskontrollen og nulpunktundersøgelsen. Der er relativt færre bedrifter med integreret svineproduktion i nulpunktundersøgelsen, men der er en tendens til, at der sker hyppigere overtrædelser på disse bedrifter, og at de også har flere overtrædelser i forhold til de sammenlignelige bedrifter i velfærdskontrollen. Endvidere viser analyserne, at bedrifterne med integreret svineproduktion i nulpunktsundersøgelsen har mere alvorlige lovovertrædelser end de tilsvarende bedrifter i velfærdskontrollen. Bedrifter klassificeret som integrerede svinebrug omfatter 58 pct. af alle observationer i det samlede datasæt (dvs. både data i velfærdskontrollen og i nulpunktsundersøgelsen under ét). Såvel forskelle i fordelingen på driftsformer som i antallet af bedrifter gør, at data i velfærdskontrollen og nulpunktsanalysen ikke kan analyseres som et samlet datasæt. Som tidligere nævnt er data i nulpunktundersøgelsen baseret på en tilfældig udvælgelse, hvilket ikke gælder i velfærdskontrollen. De statistiske analyser af sammenhængen mellem indikatorer for dyrevelfærd og økonomi er derfor udelukkende baseret på data fra nulpunktsundersøgelsen.

Beskrivende analyser

De beskrivende analyser omfatter 67 bedrifter med integreret svineproduktion og 39 bedrifter udelukkende med slagtesvineproduktion. Der var ikke tilstrækkelige data til at analysere andre driftsformer, som fx bedrifter med ren smågriseproduktion. For at være klassificeret som en bedrift med svineproduktion, og dermed indgå i analyserne, skal mindst 66 pct. af de samlede indtægter stamme fra svineproduktionen.

Ved brug af forholdsvis simple beskrivende analysemetoder er følgende hypotetiske sammenhænge mellem de definerede indikatorer for dyrevelfærd (defineret som forskellige typer af overtrædelser af dyreværnslovgivningen) og:

- antalletproduceretgrise
- dækningsbidraget pr. dyreenhed (for svin)
- dyrlægeomkostningerne pr. dyreenhed (for svin)
- indtægter pr. dyreenhed (for svin)
- foderomkostninger pr. dyreenhed (for svin)
- andre omkostninger pr. dyreenhed (for svin)
- landmandens alder
- antal år som selvstændig (som proxy for landmandens erfaringer)

analyseret. Det er valgt at fokusere på disse sammenhænge ud fra en gennemgang af den eksisterende relevante litteratur og i dialog med en række eksperter på dyrevelfærdsområdet.

Tabel 1 og 2 viser resultaterne for de statistiske tests af sammenhængene mellem de ovennævnte 8 socioøkonomiske variable og de 5 indikatorer for dyrevelfærd for bedrifter med henholdsvis integreret svineproduktion og ren slagtesvineproduktion. De identificerede signifikansniveauer er vist i noter til de to tabeller. Hvis testresultatet ikke viser nogen signifikans, er det angivet som ”Ingen” i tabellerne.

Studier refereret i den økonomiske litteratur har identificeret statistiske sammenhænge mellem indikatorer for dyrevelfærd og størrelsesforhold, men de fundne sammenhænge er langt fra entydige. De gennemførte statistiske analyser i dette projekt viser derimod ingen signifikante sammenhænge mellem antallet af svin på den ene side og på den anden side antallet og/eller karakteren af overtrædelser. Det anvendte datamateriale giver dermed ikke belæg for at hævde, at der er en generel sammenhæng mellem besætningsstørrelse og overholdelse af dyrevelfærdslovgivningen på bedrifter med svineproduktion.

Dækningsbidraget fra svineproduktion indeholder både indtægterne fra salg af svin og omkostningerne til bl.a. foder og dyrlæge. Det kan derfor forventes, at der er en sammenhæng mellem størrelsen af dækningsbidraget og niveauet af dyrevelfærd i besætningen. Sammenhængen kan imidlertid gå begge veje. Det kan hævdes, at god management kan føre til såvel et højt dækningsbidrag som høj dyrevelfærd. Omvendt kan der også argumenteres for, at høj dyrevelfærd kræver større omkostninger, som mindsker dækningsbidraget. Sammenhængene mellem de produktionsøkonomiske resultater og niveauet for dyrevelfærd i husdyrproduktionen er ikke dokumenteret i litteraturen, selvom nogle få studier har fundet evidens, som peger på en negativ sammenhæng mellem økonomisk produktivitet og dyrevelfærd.

Når det gælder bedrifter med integreret svineproduktion ses en signifikant tendens til, at der opnås et lavere dækningsbidrag, såfremt der har været en overtrædelse af dyrevelfærdslovgivningen (jf. anden række i tabel 1), hvorimod dette ikke er tilfældet for bedrifter med rene slagtesvinebesætninger (jf. anden række i tabel 2, som angiver ”Ingen” korrelation mellem dækningsbidraget og de 5 indikatorer for overtrædelser af dyrevelfærdsreglerne). Det kan muligvis forklares med, at god management (som også giver højere dyrevelfærd) er af større økonomisk betydning i integreret svineproduktion end i slagtesvineproduktionen.

Tabel 1. Test resultater for bedrifter med integreret svineproduktion

	Totale antal overtrædelser	**De mest alvorlige overtrædelser**	**Overtrædelser af enhver slags**	**Overtrædelser vedr. rode- og beskæftigelses-materiale**	**Overtrædelser vedr. syge dyr**
Antal svin	Ingen	Ingen	Ingen	Ingen	Ingen
Dækningsbidrag (DB)	Lavere DB hvis overtrædelser[a]	Der er en forskel[a]	Lavere DB hvis overtrædelser[a]	Lavere DB hvis overtrædelser[b]	Ingen
Dyrlægeomkostninger	Ingen	Ingen	Lavere omkostning hvis overtrædelser[a]	Lavere omkostning hvis overtrædelser[a]	Lavere omkostning hvis overtrædelser[b]
Indtægter	Ingen	Der er en forskel[a]	Ingen	Lavere indtægter hvis overtrædelser[c]	Ingen
Foder omkostninger	Ingen	Ingen	Ingen	Ingen	Ingen
Andre omkostninger	Ingen	Ingen	Ingen	Ingen	Ingen
Landmandens alder	Ingen	Ingen	Ingen	Ingen	Ingen
Landmandens erfaringer	Ingen	Ingen	Ingen	Ingen	Ingen

a) Signifikans på 10 pct.’s niveau; b) Signifikans på 5 pct.’s niveau; c) Signifikans på 1 pct.’s niveau.

Tabel 2. Test resultater for bedrifter med ren slagtesvineproduktion

	Totale antal overtrædelser	**De mest alvorlige overtrædelser**	**Overtrædelse af enhver slags**	**Overtrædelser vedr. rode- og beskæftigelses-materiale**	**Overtrædelser vedr. syge dyr**
Antal svin	Ingen	Ingen	Ingen	Ingen	Ingen
Dækningsbidrag (DB)	Ingen	Ingen	Ingen	Ingen	Ingen
Dyrlægeomkostninger	Ingen	Der er en forskel[a]	Højere omkostning hvis overtrædelser[a]	Ingen	Højere omkostning hvis overtrædelser[a]
Indtægter	Højere indtægterhvis overtrædelser[c]	Ingen	Lavere indtægter hvis overtrædelser[a]	Ingen	Ingen
Foder omkostninger	Ingen	Ingen	Ingen	Ingen	Ingen
Andre omkostninger	Højere andre omkostning hvis overtrædelser[a]	Ingen	Højere andre omkostning hvis overtrædelser[a]	Ingen	Højere andre omkostning hvis overtrædelser[a]
Landmandens alder	Ingen	Ingen	Ingen	Ingen	Ingen
Landmandens erfaringer	Ingen	Ingen	Ingen	Ingen	Mindre erfaringer hvis overtrædelser[a]

a) Signifikans på 10 pct.'s niveau; b) Signifikans på 5 pct.'s niveau; c) Signifikans på 1 pct.'s niveau.

De statistiske resultater viser en betydelig forskel, når det gælder sammenhængene mellem dyrlægeomkostningerne per dyreenhed på den ene side og på den anden side antallet og typen af overtrædelser i henholdsvis integrerede svinebesætninger og slagtesvinebesætninger. I de integrerede besætninger er der en tendens (signifikant på 10 pct.'s signifikansniveauet) til, at dyrelægeomkostningerne er lavere i de besætninger, hvor der er konstateret mindst en overtrædelse (jf. de tre sidste rubrikker i tredje række i tabel 1). De gennemsnitlige dyrlægeomkostninger er estimeret til 1.061 kr. pr. dyreenhed svin på bedrifter, hvor der ikke er observeret overtrædelser af reglerne vedrørende håndtering af syge svin. På bedrifter, hvor der er konstateret mindst en overtrædelse, er de gennemsnitlige dyrlægeomkostninger derimod beregnet til 857 kr. pr. dyreenhed. En mulig forklaring kan være, at producenter på de integrerede bedrifter, som investerer relativt mest i forebyggelse og gode medicinsk behandling af syge dyr, også har en højere dyrevelfærd.

Det omvendte er delvist tilfældet i de rene slagtesvinebesætninger, hvor dyrlægeomkostningerne er signifikant højere, når der er konstateret mindst en overtrædelse af de samlede regler, og der er sket en specifik overtrædelse af reglerne for håndtering af syge dyr (jf. række 3 i tabel 2). Bedrifterne uden overtrædelser har gennemsnitlige dyrlægeomkostninger på 173 kr. pr. dyreenhed, mens bedrifter med overtrædelser af reglerne for håndtering af syge slagtesvin har dyrlægeomkostninger på 232 kr. i gennemsnit pr. dyreenhed. Denne forskel er signifikant på 10 pct.'s signifikansniveauet. Det kan muligvis forklares med, at slagtesvinebedrifter med dårlig dyrevelfærd har flere syge svin og derfor højere dyrlægeomkostninger.

Sammenhængene mellem indikatorerne for dyrevelfærd og landmandens erfaringer er også blevet statistisk analyseret. To forskellige indikatorer for erfaring er blevet benyttet. Den ene er landmandens alder ud fra den antagelse, at landmandens alder er proportional med hans erfaringer med landbrugsdrift. Den anden indikator er antallet af år som selvstændig landmand. For det meste ejer landmanden den eller de samme bedrifter indtil han eller hun går på pension. Derfor vil antal år, som selvstændig landmand, være en troværdig indikator for landmandens professionelle erfaringer.

Som det fremgår af tabel 1 og 2 er der dog ingen eller kun en meget svag indikation af nogen sammenhæng mellem overtrædelser af dyreværnslovgivningen og landmandens erfaringer. For bedrifter med integreret svineproduktion kunne ikke findes nogen statistisk signifikante sammenhænge overhovedet. For rene slagtesvinebesætninger er sammenhængen mellem erfaringsniveauet og velfærdsindikatorerne også svag. Denne eneste sammenhæng identificeret gennem de statistiske analyser er, at slagtesvineproducenter med mindre landbrugserfaring tilsyneladende har flere overtrædelser af reglerne for håndtering af syge dyr i forhold til landmænd, hvor sådanne overtrædelser af dyrevelfærdsreglerne ikke er blevet observeret. Det indikerer, at jo større landbrugserfaring, jo større sandsynlighed for at kunne håndtere syge dyr i overensstemmelse med den gældende lovgivning på området.

Multivariate Analyser

Den beskrivende analyse har kun set på sammenhænge mellem to variable hver gang, selvom det må forventes, at både de økonomiske resultater og dyrevelfærd afhænger af mange faktorer. Derfor er også gennemført multivariate statistiske analyser, der giver mulighed for simultan analyse af indflydelsen af mange forskellige faktorer.

De multivariate analyser omfatter 135 bedrifter (som også omfatter bedrifter med andre driftsformer end integreret svineproduktion og slagtesvineproduktion). Både faktorer, der kan have en indflydelse på dyrevelfærd, og faktorer der kan påvirke de økonomiske resultater, er blevet undersøgt.

Hovedkonklusionen fra analyserne med indikatorer for dyrevelfærd som afhængige variable er, at overtrædelsen af lovgivningen om dyrevelfærd afhænger af driftsformen, men derimod stort set ikke afhænger af andre faktorer så som besætningsstørrelsen og landmandens erfaringer.

Resultaterne af den multivariate analyse med dækningsbidraget som den afhængige variabel viser en negativ sammenhæng mellem dækningsbidraget og overtrædelser af dyrevelfærdslovgivningen med hensyn til syge dyr; dvs. bedrifterne, der overtræder lovgivningen vedrørende håndtering af syge dyr, har i gennemsnit et lavere dækningsbidrag end bedrifterne der ikke overtræder denne lovgivning. Alle andre af de anvendte indikatorer for dyrevelfærd har ingen statistisk signifikant sammenhæng til dækningsbidragets størrelse.

Regressionsanalysen af dyrlægeomkostningerne viser, at denne omkostning stort set ikke afhænger af dyrevelfærd, men derimod af driftsformen.

De signifikante sammenhænge, som er fundet gennem de multivariate analyser, er generelt i overensstemmelse med de fundne resultater i de beskrivende analyser, men antallet af identificerede signifikante sammenhænge er mindre i de multivariate analyser end i de beskrivende analyser. De multivariate analyser sammenligner bedrifter, der har de samme karakteristika (dvs. de tager højde for ikke kun forskelle i driftsformen, men også forskelle i fx besætningstørrelse og landmandens alder og erfaring). I modsætning hertil tager de beskrivende analyser udelukkende hensyn til forskelle i driftsformen. Det er med til at forklare, hvorfor der er fundet færre signifikante sammenhænge mellem indikatorerne for dyrevelfærd og de socioøkonomiske variable i de multivariate analyser end i de beskrivende analyser.

Effektivitetsanalyser

I modsætning til de beskrivende og multivariate økonomiske analyser er det gennem effektivitetsanalyser muligt at lave en benchmarking af bedriftens samlede produktivitet og relatere denne benchmarking til de definerede indikatorer for overholdelse af dyreværnslovgivningen. Herved kan det analyseres, om der er statistisk sammenhæng mellem den samlede produktivitet og niveauet for dyrevelfærd på bedrifter med svineproduktion. Den anvendte statistiske metode betegnes som ”Stokastisk Frontier Analysis” eller kort SFA.

Effektivitetsanalysen omfatter 120 bedrifter (idet 15 bedrifter er udeladt pga. manglende oplysninger om dyrket areal og/eller arbejdsindsats). Den estimerede SFA model inkluderer 2 output variable og 6 input variable. De 2 output variable består af dels det samlede nettoudbytte i den animalske produktion i kroner, dels udbyttet fra planteproduktion og forskellige serviceydelser i kr. De 6 input variable består af: Foderforbrug i kr.; de veterinære omkostninger og diverse andre variable input i svineproduktionen opgjort i kr.; andre diverse variable omkostninger i planeproduktionen eller ikke delelige omkostninger opgjort i kr.; dyrket areal i ha; anvendt arbejdskraft i timer; og anvendt landbrugskapital i kr.

SFA resultaterne viser, at der en negativ sammenhæng mellem antallet af overtrædelser af dyreværnslovgivningen og bedriftens samlede effektivitet (dvs. bedrifter med flere overtrædelser har en lavere samlede effektivitet). Bedrifter, som overtræder reglerne vedrørende håndtering af syge dyr, har en endnu lavere tekniske effektivitet (sammenlignet med bedrifter, som har det samme totale antal af overtrædelser, men inden for andre områder af dyrevelfærdslovgivningen). Overtrædelser af reglerne vedrørende rode- og beskæftigelsesmateriale er muligvis positivt korreleret med bedriftens tekniske effektivitet, men denne sammenhæng er ikke statistisk signifikant. Samlet set falder bedriftens indtægter i gennemsnit med 0,2 procent per observeret overtrædelse. Hvis der er overtrædelser af velfærdsreglerne vedrørende håndtering af syge dyr, er bedriftens indtægter i gennemsnit reduceret med yderlige 2,5 procent.

Afslutning

Der er knyttet en række begrænsninger til de gennemførte analyser. Den første drejer sig om validiteten af målet for dyrevelfærd så som diskuteret tidligere. En anden begrænsning er, at såvel dækningsbidraget som dyrlægeomkostningerne er aggregerede økonomiske størrelser. Dyrlægeomkostningerne, og især dækningsbidraget, er aggregerede størrelser i den forstand, at de begge består af mange underposteringer gennemført i løbet af regnskabsåret. Til gengæld giver data i både velfærdskontrollen og nulpunktsundersøgelsen et øjebliksbillede. Dette billede kan være stærkt påvirket af tilfældigheder. Disse data repræsenterer derfor ikke niveauet for dyrevelfærd i en besætning i et helt år. Samlet set kan de dog godt give et retvisende billede af det gennemsnitlige velfærdsniveau i svineproduktionen, hvis det kan antages, at negative og positive tilfældigheder i velfærdskontrollen og nulpunktsundersøgelsen nogenlunde udligner hinanden.

Det skal også bemærkes, at de gennemførte analyser vedrører statistiske sammenhænge, men ikke årsagssammenhænge (dvs. kausalitet) mellem dyrevelfærd og økonomiske resultater. Resultaterne viser, at der kun er en svag statistisk sammenhæng mellem dyrevelfærd og økonomiske resultater. Ifølge analyserne afhænger overtrædelser af dyrevelfærdslovgivning af driftsformen, men fx ikke af besætningsstørrelsen. Bedrifter, der overtræder dyrevelfærdslovgivningen, har en tendens til at have et lavere dækningsbidrag (især i integreret svineproduktion) og en lavere tekniske effektivitet end de bedrifter, der overholder dyrevelfærdslovgivning. Samlet set tyder det på, at landmænd, der har styr på økonomien og har en effektiv produktion, også har bedre styr på overholdelsen af dyrevelfærdsreglerne, men mere detaljerede analyser (baseret på flere og mere detaljerede data) er nødvendige for at kunne undersøge kausaliteten mellem dyrevelfærd, de økonomiske resultater og andre relevante faktorer.

1. Introduction

1.1. Background

Farm animal welfare is continually debated in the Danish media, and it involves consumers, livestock producers, retailers and the government. Animal welfare can be important both for producers who regularly have to make production decisions that influence their animals' welfare, and for consumers who regularly have to make decisions about buying animal products (e.g. conventional products, products with animal label, organic products, or no animal products at all). The government shows willingness to implement new regulations on animal welfare, and retailers are branding products on animal welfare attributes (Dyrenes Beskyttelse 2013). The relevance of animal welfare in Denmark can be seen by the articles and opinion pieces in the major newspapers (e.g. Gjerris (2012), Politiken (2013b)). In Denmark the debate on farm animal welfare often uses the pig industry as an example, because of its relative importance in Danish livestock production. The production value of Danish animal production in 2012 was 49 billion DKK, and the pig sector was accountable for almost 23 billion DKK of this (Hansen and Andersen 2013). This level of production requires that there is a population of 12 million pigs living in the Danish stables (Danmarks Statistik 2013). These issues make the study of animal welfare relevant for society, and the importance of the pig sector makes it a relevant case study of animal welfare.

Animal welfare has traditionally been studied by ethicists, ethologists and veterinarians, but recently also gained attention by economists. In general there are four areas within the field of economics that could be of particular use for the discussion of animal welfare. These are public economics, welfare economics, consumer economics and production economics (Lusk and Norwood 2011). Public economics studies market failures, e.g. whether animal welfare has public good characteristics, which could justify government intervention such as stricter welfare legislation. Welfare economics examines the trade-offs of different policies or initiatives on consumers, taxpayers and producers and makes use of both consumer economics and production economics. The aspect of animal welfare that is most frequently analysed by economists are consumers' preferences for improved animal welfare (Lusk and Norwood, 2011, for a review see Lagerkvist and Hess, 2011).

Production economics can aid the understanding of the economic incentives of the producer in improving animal welfare. The producer is the caretaker of farm animals and his decisions on the housing system, feed quality, health management, etc. reflect his values on animal welfare, but also his desire to maximize profits. Knowledge on the relationship between economics and animal welfare can aid farmers, consultants and policy makers in discussions on management strategies or in the implementation of new welfare legislation. According to McInerney (2004), Lawrence (2009) and Lusk and Norwood (2011), there is a gap in the economic literature concerning animal welfare, especially in the field of production economics. Several studies within production economics use a modeling approach and calculate the costs of housing systems with different welfare attributes (e.g. Guy *et al.* 2012; Bornett *et al.* 2003; Lund *et al.* 2010; Seibert and Norwood 2011; Majewski *et al.* 2012; Den Ouden *et al.* 1997). Jensen et al. (2008) used a log-linear variance model to investigate the effect of diseases on the profit margin[1] of the slaughter pig production in Denmark. Jensen *et al.* (2012b) studied the severity of pain and profit losses associated with different causes of lameness. The authors used statistical simulations to quantify the animal welfare consequences (i.e. pain) and losses in profitability based on the expert opinions. Ahmadi *et al.* (2011) and Stott *et al.* (2012) use linear programming to study the effects on profits from pen systems with different welfare attributes, and from extensive sheep farming systems with different welfare scores, respectively. All these studies use data from the literature, questionnaires, interviews, and expert opinions, and most use a model farm as the outset for the calculations. There are a few studies that use a technical efficiency framework, e.g. Lawson *et al.* (2004a); Lawson *et al.* (2004b) and Barnes *et al.* (2011). Lawson *et al.* (2004a) and Lawson *et al.* (2004b) study the relationship between animal health and technical efficiency in dairy cattle production. They use stochastic frontier analysis where they apply farm accountancy data and veterinary treatment records for a large sample of farms. Barnes *et al.* (2011) employ the data envelopment analysis.

1.2. Purpose

The relevance of the animal welfare debate, the importance of the pig sector in Danish animal production, and the lack of knowledge on animal welfare within production economics are the main reasons for to addressing this issue. The aim of this study is to deliver new insights on farm animal welfare from the economic perspective. The datasets on animal welfare inspections conducted in Denmark in 2011 has been merged with farm level accountancy data on Danish pig producers. The outcome is an unique data set that allows us to study the relationship between aspects of farm animal welfare and the economic outcome of Danish pig producers.

1.3. Problem Statement

The research objective of this report is to analyze the relationship between pig welfare (using the proxy of legislative compliance in the area of animal welfare) and the economic outcome of farmers. More specifically, the research objective will be to answer the following question:

[1] The authors define profit margin (PM) in following way: PM = Revenue – Feed cost – Medicine cost – cost of piglets, where all measures are per pig unit. Since they do not account for total costs of pig production (i.e. fixed costs) their measure should be called gross margin instead of profit margin.

Is there a relationship between animal welfare and economic results at the farm level?

This question will be addressed by answering the following sub questions:

- Is there a relationship between the number of pigs produced by a farmer and pig welfare?
- Is there a relationship between gross margin per pig unit[2] and pig welfare?
- Is there a relationship between medicine and veterinary cost per pig unit and pig welfare?
- Is there a relationship between the age or experience of the farmer and pig welfare?
- Is there a relationship between the technical efficiency of a farm and pig welfare?

1.4. Methodology

In order to answer these questions we use descriptive analysis to investigate the possible relationship between the animal welfare indicators and the socio-economic variables: the number of produced animals, gross margin per pig unit, veterinary costs per pig unit, age of the farmer and experience. Descriptive analyses can be used for detecting obvious relationships between two variables. They are used because of the explorative nature of the research question. Additionally, we use linear regression methods to investigate these relationships while taking into account the effects of other variables and allowing for interactions between the explanatory variables.

Furthermore, we investigate the relationship between technical efficiency and pig welfare using a stochastic output distance function. Technical efficiency in economics is often defined as the ratio of observed output to the maximum potential output. In the analysis of technical efficiency two approaches are often used: the nonparametric Data Envelopment Analysis (DEA) and parametric Stochastic Frontier Analysis (SFA). The advantage of the SFA over the deterministic DEA is that it distinguishes between inefficiency and noise in the data and the estimation process. Stochastic events play an important role in agriculture (e.g. due to weather conditions), which could generate noise in the data. Therefore, the SFA method is chosen for the analysis of technical efficiency. Most often the concept of a primal production function is used to estimate the technical efficiency in the stochastic frontier analysis framework. However, the primal specification of a production function requires either that producers produce a single output or the researcher needs to aggregate the multiple outputs into a single aggregated output. The alternative approach that allows for the multiple-output and multiple-input production technology is the estimation of the output distance function. Economic data for these analyses is provided by the Pig Research Centre, and is based on accountancy data from Danish farmers in 2011.

[2] One pig units corresponds to 4.3 sows with piglets up to 7,3 kg; or 36 slaughter pigs from 32 kg to 107 kg; or 200 piglets between 7,3 kg and 30 kg.

As we do not have data from an overall animal welfare assessment, we will use the farm's compliance with the legislation in the area of animal welfare as a proxy of animal welfare in our analysis. The data on compliance is provided by the Danish Veterinary and Food Administration and the Danish AgriFish Agency. The data from the Danish Veterinary and Food Administration is a randomly sampled welfare inspection performed in 2011. This data will be referred to as "nulpunkt" data. The data from the Danish AgriFish Agency is also based on welfare inspection data from 2011, however this is a risk-based inspection therefore this data is not randomly sampled. This data will be referred to as welfare control data.

Animal welfare is a complex concept, and therefore this report will start out by presenting the different aspects of animal welfare followed by are view on animal welfare research in production economics literature in section 2. The data of the animal welfare inspections and its relation to pig welfare is described in section 3. In section 4 proposed indicators of animal welfare are described, and their strengths and weaknesses are discussed. The aggregation of animal welfare data that was necessary to combine the animal welfare and economic datasets is described in section 5. In section 6 the theory on the stochastic output distance function is provided. Before we proceed with the economic analysis (section 7) the two samples of animal welfare inspections are tested for potential biases of the aggregation procedure, and their poolability is assessed. The results of the conducted analyses (descriptive analyses, regression analyses and analysis of technical efficiency) of the relationship between animal welfare indicators and economic outcomes are presented in section 8. Section 9 discusses the results of the conducted analyses and section 10 concludes.

1.5. Delimitation of the Research Scope

The report takes an empirical approach to the research question, and most sections are therefore directed towards handling of data and the economic analyses. Available data has been a determinative factor for the chosen hypothesis, and the formulation of animal welfare indicators. All conclusions are entirely based on the available data.

We focus on the connection between production economics and farm animal welfare. Therefore we need to mention that we will not study animal welfare from any of the perspectives offered by public economics, welfare economics, or consumer economics. The knowledge presented in this report can be used to further the understanding of the economic incentives a Danish farmer has in complying with the animal welfare legislation.

2. Reviewing Animal Welfare

2.1. The Concept of Animal Welfare

Industrialization and intensification of modern agriculture started in 1950s resulted in changes in animal housing and animal management. Although many of these changes have led to improved animal health, at the same time they result that the animals have being kept in artificial environments (Keeling, 2005). The debate on animal well-being or animal welfare started in 1960s initiated by R. Harrison's book ``The Animal Machines'' where she introduced the term ``factory farms`` comparing animal to machines in factories. The first research on animal welfare was the report of Brambell Committee (Brambell 1965) that provided a number of recommendations which set the benchmark for the entire European development within animal welfare (Sandøe et al. 2012).

According to Sandøe (2010) the research on animal welfare is mainly undertaken within natural sciences (in ethology, pain and stress-physiology and veterinary medicine). More studies relevant to animal welfare in the other disciplines, notably sociology, economics and ethics, need however to be carried out and taken fully into account if the factors restricting and delaying improvements in animal welfare are to be identified and overcome (Appelby 2004).

The animal welfare is a wide-ranging, and often value-laden, term that is used with somewhat different meanings by different people (Sandøe 2010). In our study we take the Broom's (2008) approach to animal welfare. Broom (2008) discusses different concepts of pig welfare, which he puts into five categories: needs, feelings, stress, health and pain. These categories cover different aspects of good and poor welfare, and make a good starting point to get a grasp on the different elements that constitutes animal welfare.

2.1.1. Needs

Animals have different ranging needs, such as bodily functions controlling body temperature, nutritional state, social interactions, etc. The environment surrounding the pig is important for satisfying these needs. The body temperature, nutritional state, and social interactions need to be upheld at a certain level in order for the pig to fully cope with the environment. The stables should therefore provide certain conditions to allow these needs to be fulfilled. The needs of a pig can be characterized "*as a requirement, which is part of the basic biology of an animal, to obtain a particular resource or respond to a particular environmental or bodily stimulus*" (Broom 2008, p. 19). There are two kinds of needs. Some needs must be satisfied if life is to continue (e.g. eating), and other are needs the animal wishes to be satisfied (e.g. to root in soil or straw). If an animal strongly expresses a wish to get a need fulfilled, then it is usually an indication that it is important for its biological success, and is therefore important in assessing welfare (Broom 2008). Needs are closely linked with feelings, because when a need is unsatisfied the individual is likely to experience negative feelings, and positive feelings when the need is satisfied.

2.1.2. Feelings

The functional role of feelings is debated, with suggestions ranging from them being an epiphenomenon to having a direct causal effect on behaviour. Irrespective of the explanation, empirical findins is that feelings are often seen in situations that are related to animals attempts at coping with the environment, (Duncan and Petherick 1991); (Broom 2008). Broom (2008, p.21) states that:" *(...) whenever a situation exists where decisions are taken which have a big effect on the survival or potential reproductive output of the individual, it is likely that feelings be involved*". Contrary to other aspects of welfare, data on feelings are difficult to obtain, and is primarily given by preference studies, and indirect sources such as physiological and behavioral responses in different situations, (Dawkins 1983); (Broom 2008).

2.1.3. Stress

Stress involves the animals' failure to cope with a given situation, (Broom 2008). Controllability and predictability are significant determinants to assess whether an animal can cope with the situation. For example, the absence of food may cause stress for an animal, but if the animal is able to solve the problem by finding food, then the event is controllable, and the stress associated with the event does not have long term consequences. Predictability can help the animal mitigate the effects of the stressful situation, even though it might not be able to control the situation, (Wiepkema and Koolhaas 1993). Stressful situations occur when predictability and controllability is not possible, e.g. when the housing conditions limit the pig's possibility to escape attack by a littermate. Chronic stress is present when an adverse situation is permanent, or when a stressful element has a lasting negative effect on the animal. Stereotypies and harmful behavior, e.g. tail-biting, are typical symptoms of chronic stress, Wiepkema and Koolhaas (1993).

2.1.4. Health

Health refers to the physical state of the animal. Health is an important part of welfare, and according to many definitions of welfare health is a prerequisite for good welfare(Broom 2008). A healthy animal can however have bad welfare, e.g. when its needs are not fulfilled. The advantage of using health problems as an indicator of welfare is that in many cases the connection to suffering is clear, and health status is often recorded, (Rushen 2003).

2.1.5. Pain

The experience of pain is part of the animals' control mechanisms' response to adversity during life, and can signal that the animal is having difficulties coping with the environment. Acute pain could result in behavioral avoidance, and repeated experience of acute pain can result in learning so that potential injury could be avoided. Chronic pain can result in changed behavior which can in itself have adverse effects, e.g. lameness, (Broom 2008).

Overlapping does exist between these 5 elements of animal welfare. Examples of this are that pain, stress, poor health and unfulfilled needs are connected to negative feelings, poor health can cause stress, pain can signal poor health, etc. In sum, these elements represent different aspects of what constitutes animal welfare.

2.2. Indicators of Animal Welfare

One of the big issues in economic analysis of animal welfare is to acquire quantifiable data. Some authors argue that animal welfare is characterized by how the animal feels Duncan and Petherick (1991), or by the absence of behavioral problems (Ladewig 2005). However, both are very difficult to measure.

Curtis (2007) promote the use of animal-based indicators (e.g. the animal's health), primarily because the animal-based indicators are measurable, and moreover changes in animal-based indicators signal changes in the animal's state of being, and therefore in their welfare. The advantage of animal-based indicators is that they are closely connected to animal welfare, but it needs to be noted that they require more resources to measure than environment-based indicators of animal welfare. Environment-based indicators (e.g. space allowances) are simple to measure, but their possible relationships with animal welfare are less straightforward (Botreau *et al.* 2007b). Several authors argue for using a variety of indicators to be able to cover the multidimensional nature of animals welfare (Broom 1991); (Rushen 2003); (Christensen *et al.* 2012).

2.3. Animal Welfare and Production Economics

Several studies within animal science study the productivity of farm animals in relation to animal welfare, whereas the literature on animal welfare and production economics is scarce (Lusk and Norwood 2011). In the following we will survey the indicators that are used in the literature, and how they relate to economics.

2.3.1. Environment-based Indicators

A commonly used indicator of animal welfare is space allowance, or simply area per pig. The larger the area provided per pig, the better the welfare of the pig is considered to be. More space provides pigs with the ability to perform their natural behavior, as they are less constrained in their movements. A lack of space can stress the pigs if they are not able to escape dangerous situations. A lack of space can provoke stereotypy, which is seen for animals kept in confinement. It may also lead to tail-biting, which is painful to the pigs, and moreover may lead to infections and lower welfare both for the biting and the bitten pig. When space is too scarce hygiene deteriorates as it is difficult for the pig to separate the dunging and resting area (Jensen *et al.* 2012a). Jensen *et al.* (2012a) investigated whether the financial costs of increased space allowance might be offset by more efficient growth of the pigs, or by less manual cleaning of the pens, and therefore reduced labor costs. The effect on manual cleaning was assessed regularly, and based on this it was possible to derive the need for cleaning of the pen. Pen cleanliness was not affected by space allowances in their study, nor was increased space allowances effect on gross margin per pig statistically significant.

Pigs spend 80 % of their time lying, so adequate comfort when lying down is important for welfare (Ekkel *et al.* 2003). Provision of straw or similar rooting materials such as peat and earth, is generally considered to improve the comfort and welfare of pigs (Arey and Franklin 1995). Providing even a small quantity of straw keeps the pig busy most of the time, but there is a tendency that straw-directed behavior increases with the quantity (Day *et al.* 2002). The main function for straw for growing pigs consists of providing a stimulus for the mouth and the snout, which would otherwise be directed towards other objects in the pen or pen-mates. Straw-directed behavior reduces aggression, tail biting and stereotypy (Beattie *et al.* 1995). The hygiene in the pen can deteriorate as the use of straw increase the likelihood of the pig coming into contact with manure, and getting infections, but meanwhile the prevalence of movement disorders, hoof damage, and other leg injuries is lower on concrete floors with straw bedding (Tuyttens 2005). The provision of straw can be costly for the farmer, because the straw, storing of straw, and labor are more costly than the alternative costs of having slatted housing systems (Tuyttens 2005). A study by Sinisalo *et al.* (2012) showed that tail biting reduces average daily gain with 1 % to 3 %, and therefore the cost of straw should be seen in relation to the dynamic effects from e.g. the reduction of tail bites and leg injuries. Environmental enrichment tends to reduce undesirable behavior, but it also depends on factors such as space allowances and housing types.

Bornett *et al.* (2003) studied the costs of four different housing systems applying model calculations. The housing types studied were: fully-slatted, partly-slatted, Freedom Food housing with increased straw and space allowance, and an outdoor free-range system. The partly-slatted floor is considered to be better for the hooves of the pig than the fully-slatted, and the Freedom Food and free-range systems are considered to be more considerate of pig welfare than the slatted housing systems. The result of the study showed that feed costs were lowest in the partly-slatted floor housing system, and highest in the outdoor system. The opposite tendency was true for the housing costs. Labor costs were shown to be highest in the Freedom Food system, and labor cost of the partly- and fully-slatted floors was higher than the outdoor system. It was concluded that the partly-slatted flooring reduced costs and improved pig welfare compared to the fully-slatted flooring, and that the outdoor system had the highest rearing costs as a result of an increase in feed costs (Bornett *et al.* 2003). The higher feeding cost in the outdoor system is due to poorer feed conversion ratios, which is probably caused by higher activity levels, and increased energy consumption by the pig in order to maintain body temperature (Bornett *et al.* 2003); (Lebret *et al.* 2002); (Millet *et al.* 2005). Several studies apply a similar approach as Bornett *et al.* (2003) of studying housing systems with regard to animal welfare and production economics (Guy *et al.* 2012); (Seibert and Norwood 2011); (Lund *et al.* 2010).

2.3.2. Animal-based Indicators

Jensen *et al.* (2012b) studied the relation between lameness and profitability. Lameness was used as a measure of pain, and nine different causes of lameness were investigated. The degree of pain associated with the diseases/injuries, and the different treatment probabilities, were based on expert opinions. The probability of treatment methods was used to model the expected reductions in gross margins resulting from the diagnosis. Jensen *et al.* (2012b) showed that bone fractures caused the highest level of pain and largest reduction in gross margins. The authors conclude that it is important for the farmer to recognize the different types of lameness in the herds, because it can improve profitability and animal welfare. Lawson *et al.* (2004a) studied how lameness, metabolic and digestive disorders affected technical efficiencies in dairy herds. The most efficient producers in their study reported more incidences of lameness, ketosis and digestive disorders, whereas less efficient producers reported more incidences of milk fever. The expected negative correlation between lameness, ketosis and digestive disorders and technical efficiency was outweighed by the productivity of inputs. Lawson *et al.* (2004b) studied the relationship between technical efficiency and reproductive disorders for dairy herd. The authors did not find a negative relationship between milk production efficiency and reproductive disorders as expected, because management decisions compensated for the negative biological impact of the reproductive disorders on milk production. Barnes *et al.* (2011) analyzed the effect of lameness on technical efficiency in dairy herds by considering lameness as an input to production. They found that dairy herds with low prevalence of lameness had higher technical efficiencies, which is contrary to the results of Lawson *et al.* (2004a). Low lameness farms in Barnes *et al.* (2011) were characterised by lower labor productivity and lowerstocking density, however this was overshadowed by higher productivity of feed and forage, and an increase in milk yields compared to the farms with higher levels of lameness. They therefore argue that a whole farm perspective rather than partial indicators are required once noneconomic factors (such us lameness or other welfare indicators) are used to assess technical efficiency of the farm.

Perinatal mortality rates are high in Danish pig production, where circa 24 % of a litter dies before the age of 4 weeks, which is the normal weaning age in Denmark (Pedersen *et al.* 2010). Complications which result in the death of newborns, as opposed to still births, would generally be presumed to involve severe suffering. Typical causes of neonatal deaths are breathlessness, hypothermia, hunger and sickness. These complications can arise from aspects such as a cold environment, competition for the sows teats and lack of maternal care (Mellor and Stafford 2004). Pedersen *et al.* (2010) suggest that a reason for the high perinatal mortality rate is the breeding system in Denmark, which put much weight on the economic results of genetic characteristics, such as the sows' ability to get large litter sizes, which in turn is correlated with perinatal mortality rates. Guy *et al.* (2012) analyzed different high welfare farrowing crates, where piglet survival rates, straw-bedding for the sow and space were among the welfare parameters. They found that the high welfare farrowing system increases costs with 1.6 %, compared to the frequently used farrowing crate with lower welfare. Though, if piglet mortality rates could be reduced from 12 % in the farrowing crate to 9 % in the high welfare farrowing system, then costs would be comparable between systems, but this would depend on improved management.

2.3.3. Management as an Indicator

The farmer or the stockperson is responsible for feeding, identifying sick and aggressive pigs, and choosing the housing system. Management is therefore closely connected to the welfare of the pigs, and several studies find that proper management is important for animal welfare. Ózsvári *et al.* (2012) found that the relationship between management strategy and veterinary practice was positive and significant, and that better veterinary practice improved the performance of the farm. Therefore they conclude that management's commitment to upgrade the animal health status of the farm (through the veterinary practice) improves the performance of the farm. Munsterhjelm *et al.* (2006) evaluate the reproductive performance of sows. They use an overall measure of animal welfare, where `health and stockmanship´ is one of the indicators used. They use health-related attributes and record keeping, hygiene and maintenance of pens, as proxies for `health and stockmanship´, which they then use to evaluate animal welfare. The conclusion of their study is that stockmanship has a positive effect on the reproductive performance of sows, which is similar to the conclusion by the Scientific Veterinary Committee (1997).

2.3.4. Multidimensional Indicators

Rushen (2003) state that many animal welfare studies rely on to few measures, and therefore discuss the use of an overall welfare assessment. He points out that when integrating different measures of welfare there will typically be trade-offs between them. This complicates the interpretation of such an overall measure in terms of how the weighing of each indicator should be resolved. Nonetheless, Rushen (2003) argues that: *"(…) the approach to welfare assessment which involves documenting the full range of specific problems that exist in housing systems, is more promising"* (Rushen 2003, p. 211). The study by Stott *et al.* (2012) use an overall welfare assessment to evaluate the relationship between gross margin and animal welfare in extensive sheep farming systems. The authors analyzed the relationship between welfare scores assigned to the farms based on the expert's opinion and gross margins obtained from linear programming models. The results showed that there was no correlation between gross margin and welfare scores.

2.4. Summary

This section has shown that the definition of animal welfare is multidimensional. The discussion on the indicators of animal welfare shows that conditions in the stable and the environment of the pigs can affect welfare in several ways. From the discussion on animal welfare, welfare indicators and economics it is clear that there is a connection between animal welfare and economics. However, this connection is not straightforward, as the economic results of improved welfare depend on dynamic effects, which are often unclear. Therefore, the economic costs and benefits are not straightforward to evaluate. Most production economic studies on animal welfare use a single measure, e.g. lameness as an indicator of animal's welfare, or calculate the costs of housing systems with different welfare standards. However, in order to measure animal welfare an overall indicator grasping the multidimensionality of animal welfare should be used.

3. The Animal Welfare Inspection

The Danish inspection of the welfare of farm animals is based on departmental order nr. 1358 from December 15th 2009. Danish laws on animal welfare are grounded in EU directives, but the Danish laws are in general stricter than the minimal requirements set by the EU directives, and especially in the case of pigs (Ministry of Food, Agriculture and Fisheries of Denmark 2011a).

3.1. Inspection in Practice

Inspection of animal welfare is performed at the herd level[3]. The inspection is unannounced, so that the farmer cannot affect the findings of the inspection beforehand. The farmer or his representative is required to be present during the inspection. The presence of the daily stock keeper promotes dialogue on potential violations, so that misunderstandings do not occur, and therefore make the findings of the inspection more credible (Ministry of Food Agriculture and Fisheries of Denmark 2011b). There are different inspectors on the farms and therefore a unified evaluation of the checklist measures cannot be guaranteed. The ministry seeks to limit this through seminars, dialogue with inspectors, and by establishing guidelines for the inspection (Ministry of Food Agriculture and Fisheries of Denmark 2011b). In practice the inspection is done by using a checklist. The inspector checks all the relevant checkpoints on the list at the farm, and if a violation occurs the circumstances are noted and the severity of the violation is determined for that specific checkpoint. The Animal Protection Act applies to the individual animal, and therefore a violation is noted with no regard to the number of animals affected by that checkpoint (Ministry of Food, Agriculture and Fisheries of Denmark 2013). This means that only one violation is noted if a checkpoint is violated for either 1 pig or 10 pigs. The chance of violating the legislation therefore increases for larger producers. This fact illustrates that the inspection is not doing an assessment of animal welfare, but assessment of the animal welfare legislation (Department of Large Animal Sciences 2012).

3.2. Welfare Control Inspection

Inspection of animal welfare is done on 5 % of all herds with more than 10 farm animals or horses in Denmark, and is based on a combination of risk assessment and random sampling by the Danish Veterinary and Food Administration.

[3]The inspection is done according to the CHR number, which is an abbreviation for the Central Husbandry Register. A CHR number is an identification number given to a herd belonging to a livestock farm. A farmer can have of several CHR numbers.

3.3. "Nulpunkt" Inspection

In 2011 a separate inspection of animal welfare was conducted on pig farms. This inspection was named "Nulpunktsundersøgelsen" (base-line analysis). Pig farms were randomly selected in order to have an unbiased sample to be used as a baseline for comparison to the Welfare control. In connection with the "Nulpunktsundersøgelsen" the inspectors had a meeting to align their assessments of the checkpoints in the checklist, so that the individual assessments would be comparable (Department of Large Animal Sciences 2012).

3.4. Grading of Violations

A violation of a checklist measure can be categorized into four different degrees of severity: significant disadvantage, negligent treatment, serious negligent treatment and abuse (Ministry of Food, Agriculture and Fisheries of Denmark 2011a). Assessment criteria for the animal welfare inspection and available sanctions are presented in table 3.1.

Table 3.1. Assessment criteria for the animal welfare inspection and available sanctions

Assessment criteria	**Available sanctions**
Significant disadvantage	Admonition Injunction or reported to the police
Negligent treatment	Injunction Reported to the police
Serious negligent treatment	Reported to the police
Abuse	Reported to the police

A significant disadvantage is defined as conditions that cannot be categorized as negligent, but is to the disadvantage of the animals' welfare. If the conditions in the stable form a significant disadvantage to the pigs, then farmers will receive an admonition ("indskærpelse"). If a specific violation characterized as an admonition is observed for the same farmer within two years of the first admonition then the farmer will get an injunction or be reported to the police ("politianmeldelse").

Negligent treatment is defined as conditions where there are no basis to report the violation to the police if the condition is corrected immediately. An injunction ("påbud") is given when the negligent treatment is not serious. In some cases negligent treatment can get reported to the police if the inspection authority wishes to emphasize matters of particular importance. Negligent treatment is also reported to the police if a farmer did not comply with an injunction within the stated time limit.

Serious negligent treatment should always be reported to the police by the inspector. This could be the case for an animal with chronic ailment, which has not been treated, not been put into a hospital pen, not attended to by a veterinarian, or culled timely.

Abuse is defined for the most severe cases of maltreatment and neglect, and should also be reported to the police.

3.5. The Level of Animal Welfare in the Inspection

3.5.1. The Checklist

The checklist mainly evaluates environment-based measures. These are easier and more reliable to measure than animal-based measures. Assessing whether or not a farmer has provided pigs with rooting materials is easy to check, and assessments would therefore be consistent between inspectors, whereas an animal-based measure, such as behavior, is more difficult to assess. In the following we present an overview of the criteria in the checklist and their relation to animal welfare.

3.5.2. Management of Sick Pigs

There are several criteria in the checklist concerning proper management with regards to sick animals. Several checkpoints concern sick animals and the provision and use of sick pens. This ensures that sick animals have proper conditions to cope with their illness. Aggressions between pigs are an issue when they live in densely populated pens. Several criteria exist to ensure that procedures limit aggressions and that aggressive pigs are isolated. Aggression can cause stress amongst the pigs.

3.5.3. Management in general

This category of criteria concerns the stock keepers handling of the pigs. The farmer should ensure that pigs are able to see other pigs, that movement of pigs is done correctly, that no pigs are tethered, and that pigs are checked upon regularly. Some of these criteria are difficult to assess at an inspection, e.g. whether or not the pigs are checked upon regularly. A central criterion in this category is the proper provision of rooting materials, which is often mentioned in the literature to be an important stimulus to the pigs and their welfare.

3.5.4. Housing/Pens

Criteria concerning minimum space requirements, cleanliness of pens, the condition of the floors, and climatic conditions such as temperature adjustments are accounted for within this category. Clean floors ensure that hygiene is not problematic for health, and that it is not slippery for them to move around. In general these indicators ensure that the surroundings of the pig do not cause discomforts to the pig, which could cause stress.

3.5.5. Stables

This category of criteria concerns general aspects of the conditions of the stables, such as clean inventory, proper lighting, and no injurious elements in the stables. These criteria concerns conditions not directly affecting the conditions of the pigs, and are therefore less obviously related to animal welfare.

3.5.6. Feed and Water

These criteria require that all pigs have clean feed and water at all times. It seems counterintuitive that a farmer could violate these requirements, because his interest is in fattening pigs. There are many activities in a pig stable and therefore it could be neglected. Proper nutrition is central to uphold welfare.

3.5.7. Mutilations

This category of criteria concerns the procedures for castration, tail docking, tooth grinding, etc. These criteria ensure that the procedures are done correctly. The procedures themselves cause pain to the pigs. Having no violations within this category is therefore not analogous to good welfare of the pigs, but may limit the degree of pain associated with the procedures.

3.5.8. Recordkeeping

Recordkeeping consists of requirements on having medical records, and a self-monitoring scheme. Recordkeeping does not affect the welfare of the pigs, but it can be seen as a tool for raising the farmer's awareness on animals' welfare.

This review shows that the animal welfare inspection checks central elements of animal welfare. Not all criteria are immediately relevant for welfare, but in general they concern several different aspects of welfare, and can therefore be used as data on animal welfare. In order to apply the data as data on animal welfare it is important to be aware of the level of welfare measured.

3.6. Relationship between Animal Welfare Inspections and Animal Welfare

The legislation determines the minimum requirements for animal welfare, but the legislation is not solely the result of a concern for animal welfare and ethics, but also of political and economic interests. A proper welfare assessment should solely be an assessment of the true state of being of the animals. Assessing the true state of being of the animals means that a welfare assessment should consider the negative and positive aspects of their welfare and combine them into an overall assessment. An overall assessment of animal welfare means that good welfare on some parameters can compensate for poor welfare on other parameters (Forkman 2010).

The welfare inspection is not in itself an assessment of the state of animal welfare (Forkman 2010). The animal welfare inspection inspects the requirements set out by the legislation. This entails that a farmer abiding by the requirements of the legislation will have no violations. This does not necessarily translate into good welfare. It is possible that the animals have good welfare even though the legislation is violated, and to have poor welfare when the legislation is abided to, which could be illustrated by the checkpoints concerning mutilations mentioned above. Inspection of animal welfare evaluates each requirement in the legislation, so it is not possible for the farmer to compensate a violation by improving animal welfare in other aspects. The requirements in the legislation exist to deter and stop poor animal welfare, and therefore risk factors are present in the legislation. Risk factors are an important part of the legislation, because the regular welfare control inspections are only done on a sample of farms. The welfare control inspection of a risk-based sample of farms (described in section 3.2.) and the "nulpunkt" inspection of a random sample of farms (described in section 3.3.) checked the same animal welfare regulations but Forkman (2010) argues that the "nulpunkt" inspection was stricter than the regular welfare control inspections.

3.7. Theoretical Considerations about the Relationship between Animal Welfare and Productivity

McInerney (2004) discusses the connection between animal welfare levels and livestock productivity (see figure 3.1.). He argues that there is an unacceptable level of animal welfare, which is represented by the line between point W_{min} to point D. This level of animal welfare symbolizes neglect, abuse and cruelty, and any point below this line is unacceptable. Point "A" on figure 3.1. shows the natural welfare of the animals. In this situation the animals live in the wild and exhibit their natural behavior, and therefore entail no effort on livestock producers. Livestock producers could theoretically improve the animals' welfare above their natural welfare to point "B", e.g. by providing them with shelter from predators, and sufficient food at all times. However, livestock producers are businessmen and wish to increase productivity. Therefore they make efficient use of inputs, such as limiting the space per animal and maximizing the turnover rates in the stables. This will decrease the welfare of the animals towards point C, D or E in figure 3.1. McInerney (2004)further argues that livestock producers are required to secure a minimum level of animal welfare, because both the individual farmer and the public have an interest in setting an acceptable limit, so that the welfare of livestock is at least acceptable. The level of animal welfare that is desired by different actors (e.g. consumers, producers, animal rights activists, politicians etc.) is likely to be higher than the minimum welfare. Figure 3.1.illustrates this point, and that the desired level is somewhere around point C, i.e. below maximal welfare and above minimal welfare. We have used this figure to show the connection between livestock productivity and animal welfare. The level of animal welfare which is governed by the animal welfare legislation lies in the area of point C.

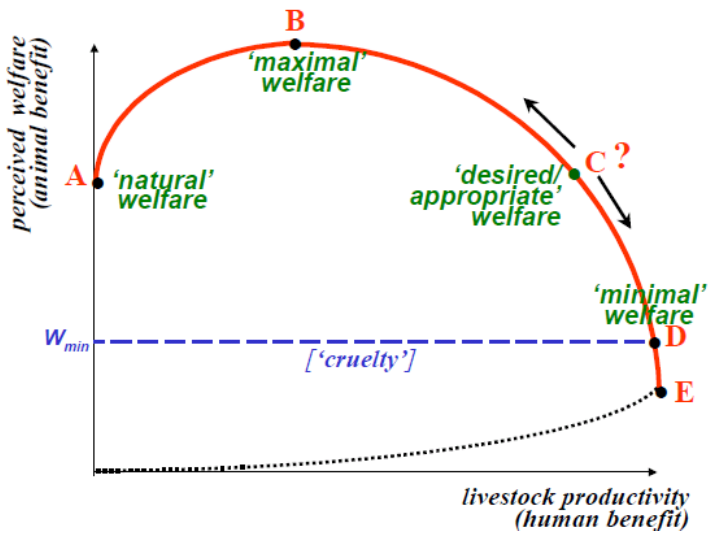

Figure 3.1. Conflicts between animal welfare and productivity (Source: McInerney 2004).

As discussed previously, welfare inspection cannot be compared to a welfare assessment, but we can argue that it can be used as an indicator of animal welfare as long as the caveats of the data are understood. According to the argumentation above farmers with no violations can have a level of animal welfare corresponding to point C or above.

At the figure 3.2.we present a slightly modified theoretical model of the relationship between productivity and animal welfare that we find more helpful as a theoretical basis of our empirical analysis. For instance, figure 3.2 does not show a unique "unacceptable level of animal welfare," because it is impossible to objectively defined this level in practice, as different people have different perceptions of which treatment of animals is acceptable and which treatment is unacceptable. Productivity is defined as the ratio of the output quantity to the input quantity. In case of multiple outputs and/or multiple inputs, an aggregated output quantity and/or an aggregated input quantity can be used. At an extremely low animal welfare level, the animals are suffering so much that the productivity is very low (i.e. low output quantities and relatively large input quantities e.g. due to sickness, mortality, etc.). With increasing animal welfare up to a certain level W_1, the animals are thriving better, which results in higher productivity, e.g. due to higher growth rates, higher reproduction rates, lower mortality and lower veterinary costs. But if animal welfare should be increased above level W_1 (point "E" in figure 3.2), an increase of the inputs (e.g. more space per animal, more opportunities for playing and rooting) results in a less-than-proportional increase of the output (or even in an unchanged (constant) or decreased(lower) output) so that the productivity decreases.

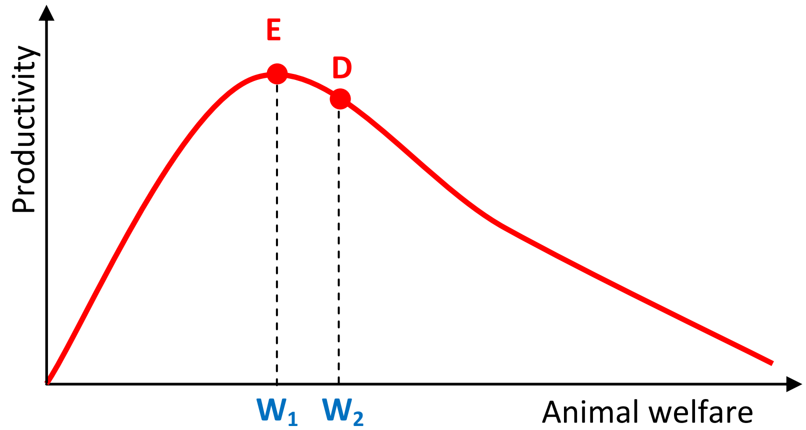

Figure 3.2. Relationship between animal welfare and productivity

If farmers are price takers and appropriate weights are used for aggregating outputs and inputs, then productivity corresponds to profitability. Therefore, in the absence of animal welfare regulations, rational farmers who have no intrinsic motivation in complying with animal welfare regulations and just maximize their profit, will choose the animal welfare level W_1 that results in the highest productivity (point "E" in figure3.2). Thus, farmers have an economic incentive to have an animal welfare of at least level W_1. It is fair to assume that many people desire a higher level of animal welfare than level W_1. Hence, the regulator (e.g. policy makers at the national or international level) introduces minimal requirements regarding the animal welfare that are higher than level W_1, e.g. level W_2 in figure 3.2. If farmers follow these animal welfare regulations, their productivity and economic profit will be lower than at the animal welfare level W_1.Farmers could only gain from further increasing animal welfare, if they get a price premium (e.g. if the final products are labeled as animal welfare friendly and some consumers are willing to pay a price premium for these products).

Welfare inspections check whether farmers comply with the animal welfare regulation, i.e. whether the actual animal welfare is below the legally required level of animal welfare. Thus, these data do not indicate how much the animal welfare level is above the legally required minimum level of animal welfare level W_2 (corresponding to point D in figure 3.1). However, there is a strong indication that farmers who violate animal welfare legislation have animal welfare levels below level W_2. The distance between the actual level of animal welfare and the legally required level of animal welfare depends on the type of the violation and its severity. As mentioned above, having violations of the animal welfare regulations does not rule out the possibility that the animals have good welfare, because the inspection solely checks the legislation and does not account for a possible substitutability between different aspects of animal welfare. By identifying the importance of the different requirements and the amount and severity of violations, it is possible to get a clearer image of the state of animal welfare for farms not abiding by the requirements.

If all farmers have at least an animal welfare corresponding to the level of W_1 denoted at the figure 3.2, there would be (everything else equal) a negative relationship between animal welfare and productivity. However, if some farmers have animal welfare levels that are significantly below W_1, there might be (everything else equal) no relationship or even a positive relationship between animal welfare and productivity.

The (observed) relationship between animal welfare and productivity can also be affected by other variables that affect both animal welfare and productivity. This indirect relationship between animal welfare and productivity could be caused, for instance, by the quality of the management (See figure 3.3). If good (bad) herd managers are (not) able to achieve a high productivity as well as a sufficiently high level of animal welfare and if there was not a direct relationship between animal welfare and productivity, we would find a positive relationship between animal welfare and productivity. If both direct and indirect relationships between animal welfare and productivity are present, then the observed relationship is their combination. Thus, if our results indicate that there is no (clear) relationship between animal welfare and productivity, it could be that there are significant direct and indirect relationships but these relationships outweigh each other.

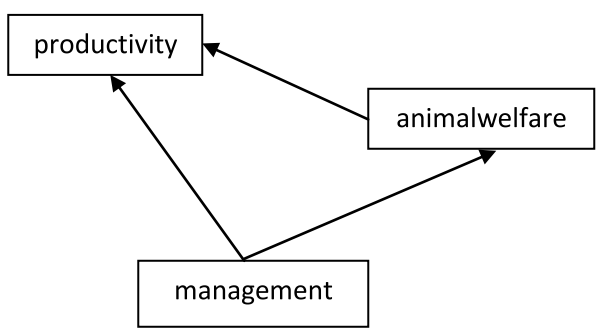

Figure 3.3. Relationship between management quality, animal welfare, and productivity

Figure 3.4 provides a more detailed model of the relationship between management, animal welfare and productivity. Animal welfare depends on the herd management and the input quantities (e.g. space per animal, medicine for preventing and curing diseases).The output quantity depends on the input quantities (e.g. stable, labour, feed, medicine), the animal welfare (explanations see above) and the quality of the management. The productivity is just the ratio of the output quantity to the aggregate input quantity (explanations see above).We assume that productivity does not have a direct causal effect on animal welfare.[4]

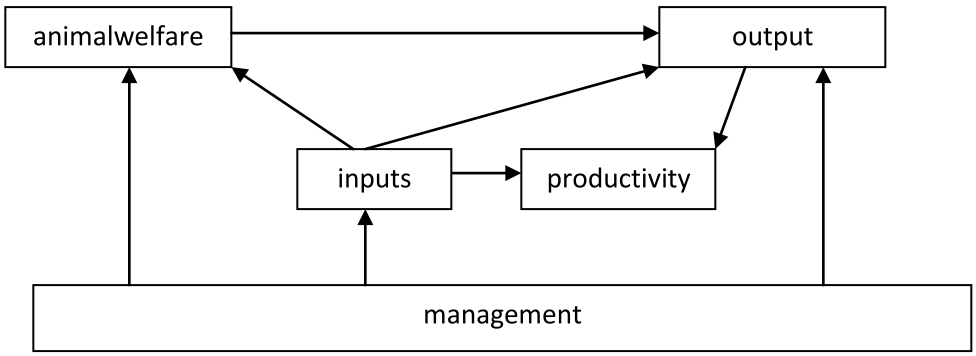

Figure 3.4. Detailed relationship between management quality, animal welfare, and productivity

[4] It might be argued that high or low productivity might affect the farmer's motivation and his/her decisions that affect animal welfare but we think that these effects are negligible.

4. Proposed Indicators of Animal welfare

In order to exploit the data in the best way we propose several indexes of the animal welfare data. The constructions of these variables are essential for evaluating animal welfare. In the following we will list and discuss the traits of potential indicators of animal welfare.

4.1. Any Violation

One way to investigate the economic differences between livestock producers is to compare producers with or without violations of the animal welfare legislation (AnyViolation). This is a simplistic way of evaluating differences between producers. The severity of sanctions, a violation's relation to animal welfare, and the number of violations are not accounted for with this indicator. This variable is therefore not an ideal indicator of animal welfare, but can instead be used to indicate if there is a difference between producers who abide by the animal welfare legislation and those who do not.

4.2. Total Number of Violations

Another indicator of animal welfare is the total number of violations. It is obtained by counting all violations of the animal welfare legislation for each farmer. In contrast to the indicator AnyViolation, this indicator accounts for differences among violators. It also captures the effect of violations within different dimensions of animal welfare, and therefore comes closer to the ideal of a multidimensional index of animal welfare (Botreau *et al.* 2007a; Rushen 2003). However, simply counting the violations assigns less importance to the dimensions of animal welfare that are described by fewer checklist points (Botreau *et al.* 2007b).Hence, using the total number of violations as an indicator of animal welfare could be problematic if the importance of the different dimensions of animal welfare does not correspond to the number of checklist points. For instance, for slaughter pigs there are five checklist points concerning sick pigs and only one checklist point concerning playing and rooting materials, but both are important for welfare.

Counting the total number of violations does not account for the severity of the sanctions or the violations' relation to animal welfare. This means that there could be instances where a farmer has several violations with minor sanctions for violations, and where the violations are only weakly related to animal welfare. The opposite scenario could also be true: a farmer having few violations with severe sanctions, and where the violations are strongly related to animal welfare. Under these circumstances the total number of violations would be a poor indicator of animal welfare. However, the variable could be used as an indicator of the management of animal welfare, because one could argue that the more violations the less emphasis a farmer puts on the animal welfare legislation.

4.3. Most Severe Violation

Using the most severe violation as a variable will provide a categorical variable, which does not take into account the violation's relation to animal welfare or the number of violations. On the other hand, it does take into account the severity of the sanction. There are differences amongst the sanctions when interpreting it in connection to animal welfare. An admonition for a violation with weak connection to animal welfare is not a strong indicator of animal welfare, because it could have been given for unfortunate one-time events. In order to get reported to the police a farmer has severely disregarded animal welfare, or has violated the same checklist point more than once. Therefore, a police report is a stronger indicator of bad animal welfare than an admonition. Another caveat is the possibility of farmers to have several violations of the most severe violation. This would reduce the comparability of farmers within the groups when compared to farmers only having one violation of the most severe violation.

In table 4.1 the traits of the different indicators are listed. This illustrates that none of the indicators ensures a direct focus on the connection to animal welfare. It would be possible to construct a composite indicator that takes account of all the traits. In order to construct a composite indicator a weighting scheme would be necessary. Adding weights to the number of violations, severity of sanctions, and the different checklist points would require much knowledge and judgment on animal welfare. Weighting schemes typically requires experts to do the weighting, and the final index would depend largely on their weightings (Botreau *et al.* 2007a). As mentioned in Botreau *et al.* (2007a) the background of the expert, veterinarian or ethologist, may affect the expert's weighting. Therefore we choose not to construct a composite indicator, but settle with the already mentioned variables, which are simple, objective and independent of weightings.

Table 4.1. Proposed Indicators of animal welfare and their traits

Traits of variable / Name of variable	Number of violations	Severity of sanctions	Ensures a direct connection to animal welfare
AnyViolation	No	No	No
Total violations	Yes	No	No
Most severe violation	No	Yes	No

4.4. Rooting Materials and Sick Animals

Table 4.1. illustrates that none of these indicators ensures a direct connection to animal welfare. This could be overcome by choosing some checklist points that have a clear connection to animal welfare, and use them as

indicators of animal welfare. The most relevant checklist points are those concerning sick animals and access to rooting and playing materials[5]. The indicator AnyRooting indicates whether a farmer violates any animal welfare regulations concerning rooting and playing materials, while the indicator AnySick indicates whether the farmer violates any animalwelfare regulations concerning sick animals. It would have been preferable to construct two additional indicators by taking into account the most severe violations in these parts of the animal welfare regulations, but there is not enough variation of the severity of the violations in our data in order to account for severity in the statistical analysis.

[5] Proper care and avoidance of suffering was also selected, but since there were less than 5% of farms which have violations within this indicator (6 farms in Nulpunkt and 5 in Welfare control) it has not been finally used in analyses.

5. Aggregation

5.1. Merging Animal Welfare Data with Economic Data

Economic data is registered on the CVR[6] number which is the identification number of a company. Within agriculture this is comparable to the use of the term “farm”. The welfare inspection data is registered on the CHR number. The CHR number is attached to a specific property (a herd) and not the entire farm. A farmer can have several herds with farm animals, and therefore several CHR numbers. If a farmer has four CHR numbers attached to the CVR number then animal welfare inspection can be conducted on e.g. two CHR numbers out of four CHR numbers. This means that there is not inspection data on all the pigs at a farm. This is of importance to the economic analysis in the following sections, because the economic data is registered for the entire farm, i.e. at the CVR number. The welfare data needs to be aggregated to the CVR number in order to do the economic analysis. In the following we will describe the different conceptual issues of the data, and how these are solved.

In order to illustrate the different checklists and the different sanctions in table 5.1-5.4, we have randomly chosen the checklist points A15, C131, C145 and H321, and some sanctions chosen for pedagogical reasons. These sanctions are abbreviated so that no violation is equivalent to “OK”, an admonition is “IND”, an injunction is “Paab”, and police report is “PA”. The indicators “total number of violations,”“most severe violation and AnyViolation are included to illustrate the effect of the aggregation procedure. In this case there are two different CVR numbers, and each has one CHR number with 3000 and 2000 pigs, respectively. Table 5.1 illustrates the structure of the animal welfare dataset in the first case of relevance for the aggregation procedure.

5.1.1. Aggregation when one out of one CHR number belonging to the CVR number is inspected

This is the simple situation where one CVR number has only a single CHR number. It also symbolizes the ideal and final situation where animal welfare data is aggregated to the CVR number. Table 5.1 illustrates that the CVR (1) have 3 violations, the most severe violation is “police report”, and it is “TRUE” that CVR (1) has any violations of the checklist points.

[6] CVR is an abbreviation of Central Business Register. In order to avoid confusion in this section we use the naming CVR and CHR numbers, and not farm and herd, respectively.

Table 5.1. Aggregation when one out of one CHR number belonging to the CVR number is inspected

CVR	CHR	Pigs	A15	C131	C145	H321	Total number of violations	Most severe violation	AnyViolation
1	1	3000	OK	IND	Paab	PA	3	PA	TRUE
2	1	2000	OK	IND	OK	OK	1	IND	TRUE

5.1.2. Aggregation when two out of two CHR numbers belonging to the CVR number are inspected

This situation is similar to the situation in section 5.1.1, because the welfare inspection was done at all the CHR numbers that belong to the CVR number. The inspection at two different CHR numbers could be argued to be similar to an inspection done at a single CHR number having the same number of pigs as CHR (1) and CHR (2) together. This would suggest that the most severe violations for each checkpoint are kept after aggregating the two CHR numbers. This is illustrated in the final row of the table below. It is worth noting that the total number of violations has increased and the most severe violation has changed in this example.

Table 5.2. Aggregation when two out of two CHR numbers belonging to the CVR number are inspected

CVR	CHR	Pigs	A15	C131	C145	H321	Total number of violations	Most severe violation	AnyViolation
1	1	1000	OK	IND	IND	IND	3	IND	TRUE
	2	2000	Paab	OK	Paab	IND	3	Paab	TRUE
Aggregation of CHR 1 and 2									
1	1+2	3000	Paab	IND	Paab	IND	4	Paab	TRUE

5.1.3. Aggregation when one out of two CHR numbers belonging to the CVR number is inspected

It is often the case that the animal welfare inspection has not been conducted at all herds (all CHR numbers) of a farm (CVR number). In this case, only the animal welfare data from theinspected herd is used in the aggregation procedure. This implies that a hypothetical inspection of the “uninspected” herd (CHR 2) would not result in any violation of the animal welfare regulations that has not been already violated in the inspected herd.

Table 5.3. Aggregation when one out of two CHR numbers belonging to the CVR number is inspected

CVR	CHR	Pigs	A15	C131	C145	H321	Total number of violations	Most severe violation	AnyViolation
1	1	2000	OK	IND	Paab	Paab	3	Paab	TRUE
	2	3000	-	-	-	-	-	-	-
Aggregation									
1	1+2	5000	OK	IND	Paab	Paab	3	Paab	TRUE

5.1.4. Aggregation when 2 out of 4 CHR numbers belonging to the CVR number are inspected.

In this case, there is not information on all CHR numbers, but there is information on more than one CHR number. In order to simplify the missing data problem, the aggregation approach from section 5.1.2 is applied to aggregate the inspected herds (CHR numbers). This result can be seen in the final two rows. In the example there is inspection data on the CHR numbers 1 and 4, and therefore these are merged. The CHR numbers 2 and 3 are also merged, but there is only data on the number of pigs. This result reduces to a situation similar to the situation in section 5.1.3 with two CHR numbers.

Table 5.4. Aggregation when 2 out of 4 CHR numbers belonging to the CVR number are inspected

CVR	CHR	Pigs	A15	C131	C145	H321	Total number of violations	Most severe violation	AnyViolation
1	1	1000	OK	IND	Paab	Paab	3	Paab	TRUE
	2	2000	-	-	-	-	-	-	-
	3	1500	-	-	-	-	-	-	-
	4	2500	OK	IND	OK	Paab	2	Paab	TRUE
Aggregation of CHR 1 and 4, of 2 and 3, and of all four herds									
1	1+4	3500	OK	IND	Paab	Paab	3	Paab	TRUE
	2+3	3500	-	-	-	-	-	-	-
1	1+2+3+4	7000	OK	IND	Paab	Paab	3	Paab	TRUE

6. Methodology

6.1. Multivariate regression analysis

The purpose of regression analysis is to evaluate the effects of one or more explanatory variables on a single dependent variable. This is done by evaluating the conditional expectation of the dependent variable given the explanatory variables: $E[y|x]$, which can be expressed as:

$$y=f(x;\alpha)+\varepsilon,$$

Where, y is the dependent variable, x is a set of explanatory variables, α is a vector of parameters to be estimated, f(.) denotes the unknown regression function and ε is a random error term.

The advantage of multivariate regression over correlation analysis is that multivariate regression analysis can investigate the relationship between many variables, accounting both for direct and indirect relationships. If the regression function is linear (in parameters), the ordinary least squares (OLS) method is the most straightforward approach for estimating the unknown parameters. However, once the dependent variable is a non-continuous count variable (i.e. only containing positive integer values), then the basic OLS model is not appropriate. In such cases, count data models such as the Poisson model or its generalizations, e.g. the negative binomial regression model is the most suitable model specification.

If the number of outcomes of the dependent variable is limited to only two alternatives (e.g. success and failure), discrete response (binary outcome) models are most suitable. In these models the interest lies in the response probability of success given the values of independent variables:

$$p(x)\equiv P(y=1|x)=G(x;\alpha),$$

where p(x) is response probability distribution, P(.) denotes probability, x is a vector of explanatory variables and G(.) is a cumulative distribution function (cdf).

Often G(.) is specified either as standard normal cdf (probit model) or as logistic cdf (logit model) and the method of maximum likelihood estimation (MLE) is applied to obtain estimates of the parameters of interest.

6.2. Stochastic Frontier Output Distance Function

This section describes the framework that we use to estimate technical efficiencies of the pig producers in our data set. In order to achieve this we present the distance function and some intuition on the term “technical efficiency”. This will provide a basis for the discussion of the estimation of the output distance function within a Stochastic Frontier Analysis (SFA) framework.

In applied production analysis usually either production functions or cost functions are used to estimate the efficiency at the sector level or the individual (e.g. farm) level. The production function only allows for the estimation of a single output. However, most pig producers in Denmark also produce crops. Since Danish pig farmers produce multiple outputs, an estimation procedure that can model multiple outputs is required. The cost function is often used in these cases. However, as input prices do not substantially differ between regions in Denmark, it is impossible to estimate a cost function without cross-sectional data. In such cases, an output distance function that can handle multiple inputs and multiple outputs and does not require price data is often used. For these reasons the output distance function is used in the analysis.

In the following we describe the output distance function and its properties that can be derived from microeconomic production theory. This section is based on the Coelli *et al.* (2005) and Bogetoft and Otto (2010). We use the Shephard's definition of an output distance measure (i.e. $TE = y/y^* \Leftrightarrow y = TE \cdot y^*$, where TE denotes technical efficiency, y is the observed output and y^* is the output at the frontier), as opposed to using the Farrell distance measure (Bogetoft and Otto 2010).

For a given production technology set, P, defined by:

$$P=\{(x,y): x \text{ can produce } y\}$$

the output set, P(x), given by:

$$P(x)=\{y: x \text{ can produce } y\}=\{y:(x,y)\in P\}$$

represents the set of all output vectors, y, which can be produced using the input vector, x.

The Shephard's output distance function D_o is defined on the output set, P(x), as:

$$D_o(x,y)= \min\left\{\delta>0: \left(\frac{y}{\delta}\right)\in P(x)\right\}$$

The properties of the output distance function are given in Coelli *et al.* (2005):

1) $D_o(x,0)=0$ for all non-negative x;
2) $D_o(x,y)$ is non-decreasing in y and non-increasing in x;
3) $D_o(x,y)$ is linearly homogeneous in y;
4) $D_o(x,y)$ is quasi-convex in x and convex in y;
5) if y belongs to the output set (production possibility set) of x, then $D_o(x,y)\leq 1$; and
6) if y belongs to the frontier of the production possibility set, then $D_o(x,y)=1$.

Property 1 states that it is possible to produce nothing from a given set of inputs, and in this case the distance measure is zero. Property 2 states that the output distance function will not decrease when y increases and it will not increase when x increases. A producer can therefore not be less efficient if he produces more with the same inputs. Property 3 concerning linear homogeneity in output quantities requires:

$$D_o(x,t\cdot y)=\min\left\{\delta \mid \left(x,\frac{t\cdot y}{\delta}\right)\in P(x)\right\}$$

$$D_o(x,t\cdot y)=\min\left\{\lambda\cdot t \mid \left(x,\frac{y}{\lambda}\right)\in P(x)\right\},\quad \left(\frac{\delta}{t}=\lambda\right)$$

$$D_o(x,t\cdot y)=t\cdot\min\left\{\lambda \mid \left(x,\frac{y}{\lambda}\right)\in P(x)\right\}$$

$$D_o(x,t\cdot y)=t\cdot D_o(x,y)$$

Property 4 implies that if inputs x^1 and x^2 can produce y then any weighted average of these inputs can also produce y (quasi-convexity in x) and that if two combinations of outputs y^1 and y^2 can be produced using input vector, x, then any weighted average of these output can be also produced (convexity in y). Therefore convexity serves the role of enlarging the technology (Bogetoft and Otto 2010, p. 64).

Property 5 and 6 state that the distance function will not exceed the value of 1, and this is because the frontier represents the maximum attainable output.

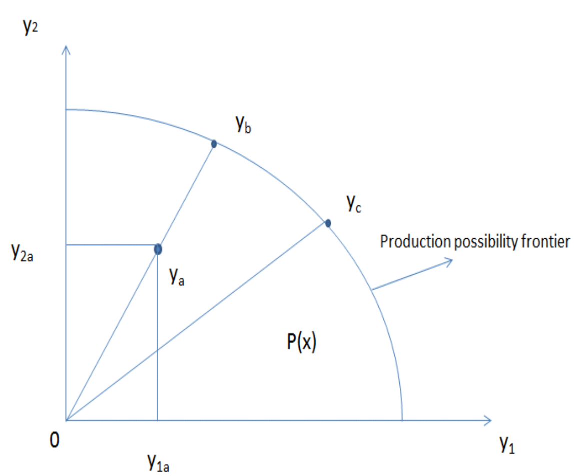

Figure 6.1. Output distance function and the production possibility set Coelli *et al.* (2005)

Figure 6.1. shows the production possibility set, P(x), which is bounded by the production possibility frontier. It shows output y_1 and y_2, which is produced with the use of an input vector x. Given the input vector x it is not possible to produce outside the production possibility set (property 5 and 6), and therefore the frontier

displays the maximum attainable output combinations. The value of the distance function for the output combination y_a is

$$\delta = 0y_a/0y_b.$$

This value is below 1, because it is the actual output combination y_a compared to the maximum attainable combination of output y_b. This is a measure of technical efficiency. The reciprocal of this factor is what all output quantities at point y_a could be increased without increasing input use, i.e. if the producer became more efficient. Technical efficiency is measured along a ray from the origin to the observed point of production. This means that the proportions of outputs are held constant along the ray, and therefore that a change in the unit of measurement will not affect technical efficiencies. The efficiency measurement is therefore unit invariant (Coelli *et al.* 2005).

6.2.1. The Stochastic Frontier Model

The linearized form of the Cobb-Douglas production function that is often used for regression analysis can be written as the following:

$$\ln(y_i) = \ln(f(x_i;\beta)) + \varepsilon_i,$$

where(ε_i)is an error term that accounts for random noise and differences in technical efficiencies. In regression analysis the method of Ordinary Least Squares (OLS) is often used, but this method interprets all deviations from the estimated regression function as noise, and the inefficiency cannot be identified. Estimating the production function with OLS means that observations can lie above the regression function, because it minimizes the sum of squared vertical distances between the predicted outputs and the observed outputs. Using OLS may therefore contradict the definition of the production frontier, because the production frontier represents the maximum attainable output at a given input vector.

The stochastic frontier model that was independently proposed by Aigner *et al.* (1977) and Meeusen and Broeck (1977) can be used to estimate a production function that accounts both for random noise and inefficiencies of the producers:

$$\ln(y_i) = \ln\left(f(x_i;\beta)\right) + v_i - u_i \text{ with } u_i \geq 0,$$

where v_i accounts for noise, and u_i accounts for technical inefficiency. One reason for estimating a stochastic frontier model is to obtain predictions of the technical inefficiencies while allowing for noise in the model. Noise can have a positive or a negative effect on output, and can therefore cause observations to lie above or beneath the frontier. The frontier represents the maximum attainable output and inefficiency will therefore always have a negative effect on the output of a producer.

In the SFA model it is assumed that v_i's are independently and identically distributed and have zero means and variancesσ_v^2, i.e. $v_i \sim$ iid $N(0,\sigma_v^2)$. It is assumed that the u_i's follow a truncated normal distribution, i.e. $u_i \sim$ iid $N^+(\mu_i,\sigma_u^2)$ (Battese and Coelli 1995). The stochastic frontier model can be estimated using the Maximum Likelihood method. The Maximum Likelihood estimation maximizes the match between the statistical model and the dataset by choosing the value of the parameters that make the values of the actual observations as likely as possible. The Maximum Likelihood estimation is done through an iterative optimization procedure. In order to separate the effect of the u_i's and v_i's for all producers two additional parameters are estimated, γ andσ^2. These are related in the following way:

$$\gamma=\frac{\sigma_u^2}{\sigma^2} \text{ where } \sigma^2=\sigma_v^2+\sigma_u^2 \text{ and } \gamma\in[0,1]$$

When γ tends to 0, then deviations from the frontier are due to the dominance of noise in the data, σ_v^2, and there are no technical inefficiencies. In this case the estimation result would approach that of the ordinary least squares estimation procedure. On the other hand, when $\gamma\rightarrow 1$ deviations from the frontier are due to the dominance of, σ_u^2, and therefore technical inefficiencies (Coelli *et al.* 2005).

6.2.2. Stochastic Output Distance Function

In order to enable the econometric estimation of the stochastic frontier production model with multiple outputs, we need to specify the output distance function. The functional form that is used for the estimation be linearly homogeneous in the output quantities (property 3):

$$D_o(x,y)=f(x,y)$$

$$f(x,t\cdot y)=t\cdot f(x,y)$$

If $t=\frac{1}{y_1}$, then the function can be written as:

$$f\left(x,\frac{y}{y_1}\right)=\frac{f(x,y)}{y_1}$$

$$f(x,y)=f\left(x,\frac{y}{y_1}\right)\cdot y_1$$

Substituting this into the equation of the output distance function, we get:

$$D_o(x,y)= f\left(x,\frac{y}{y_1}\right)\cdot y_1$$

$$\frac{D_o(x,y)}{y_1}= f\left(x,\frac{y}{y_1}\right)$$

$$\frac{1}{y_1}= \frac{f\left(x,\frac{y}{y_1}\right)}{D_o(x,y)}$$

Taking the natural logarithm on both sides of this equation yields, we get:

$$-\ln(y_1) = \ln\left(f\left(x,\frac{y}{y_1}\right)\right) - \ln(D_o(x,y))$$

Remember that $0<D_o(x,y)\leq 1$ as long as the firm is producing a positive quantity of at least one output. This implies that $-\infty< \ln(D_o) \leq 0$ so that we can set $u=-\ln(D_o)\geq 0$. Substituting u for $-\ln(D_o)$ gives:

$$-\ln(y_1) = \ln\left(f\left(x,\frac{y}{y_1}\right)\right) + u$$

The random error term v is then added to the equation to turn it into a stochastic model:

$$-\ln(y_1) = \ln\left(f\left(x,\frac{y}{y_1}\right)\right) + u + v$$

This equation is now of the form of the stochastic frontier model. Therefore, SFA estimation methods can be applied to estimate this equation, i.e. a multiple-output and multiple-input production technology.

6.2.3. Cobb-Douglas Stochastic Output Distance Function

The choice of functional form is important for the estimation and description of the production technology. Many studies within production economics apply the translog functional form, because it is second order flexible. This also means that more parameters need to be estimated than in less flexible functional forms (e.g. Cobb-Douglas), and therefore more observations are required for the estimation. We chose to apply the Cobb-Douglas functional form, because it relies on fewer parameters to be estimated. This comes at a cost, because the distance elasticities of the inputs and outputs are constant and do not vary across observations so that the elasticity of scale which is defined as the negative sum of the distance elasticities of the inputs is also constant (Coelli *et al.* 2005).

The estimable equation is:

$$-\ln\left(y_{1i}\right)=\alpha_0+\sum_{k=2}^{M}\alpha_k\ln\left(\frac{y_{ki}}{y_{1i}}\right)+\sum_{k=1}^{N}\beta_k\ln(x_{ki})+\sum_{m=1}^{L}\rho_m H_{mi}+v_i+u_i,$$

where the subscript i indicates the producer, M is the number of outputs (y), Nis the number of inputs (x), H is a set of L further explanatory variables that may affect the frontier, and α, β and ρ are the parameters to be estimated. A model of the technical inefficiencies and its explanatory variables can be estimated simultaneously with the stochastic frontier model (Battese and Coelli 1995). The model for the technical inefficiency is given by:

$$\mu_i=\delta_0+\sum_{n=1}^{O}\delta_n z_{ni} \text{ with } u_i\sim N^+\left(\mu_i,\sigma_\mu^2\right),$$

where *z* are the explanatory variables, *δ* are parameters to be estimated, and O is the number of z-variables. The actual prediction of the technical efficiencies will not be described in this report, but we refer to Coelli *et al.* (2005) for a detailed description. The inefficiency equation above appears simple, but the interpretation of the coefficients is not straightforward. The sign of the coefficient can be interpreted but not the magnitude. The formula for the marginal effect of a z-variable is derived in Olsen and Henningsen (2011) and the marginal effects can be retrieved using the add-on package “frontier” (Coelli and Henningsen 2012) for the statistical software “R”.

7. Analyzing the Data on Animal Welfare

As already discussed, the animal welfare data are based on the "nulpunkt" data and the welfare control data. There are some potential biases in the data, which are common for both datasets. Some farms have been inspected at more than one herd, and some farms have been inspected at a higher share of their herds. This will be investigated to see if it has an effect on the number or severity of violations. The distributions of the animal welfare indicators will be assessed across the datasets in order to decide whether it is reasonable to pool the data, and approach it as one sample. In the welfare control data there are 126 observations, and in "nulpunkt" data there are 138 observations.

7.1. Testing for Bias

7.1.1. Herds Inspected

In the "nulpunkt" data set most farms are inspected at only one herd, whereas it happens more frequently in the welfare control data set that farms are inspected at more than one herd. As shown in section 5.1.3. concerning the aggregation procedure, it is assumed that farms with more than one herd inspected can be approached as if they were one big herd having an inspection. This could be a strong assumption, and it is therefore tested. Figure 7.1 shows the number of herds inspected for the farms in the two samples.

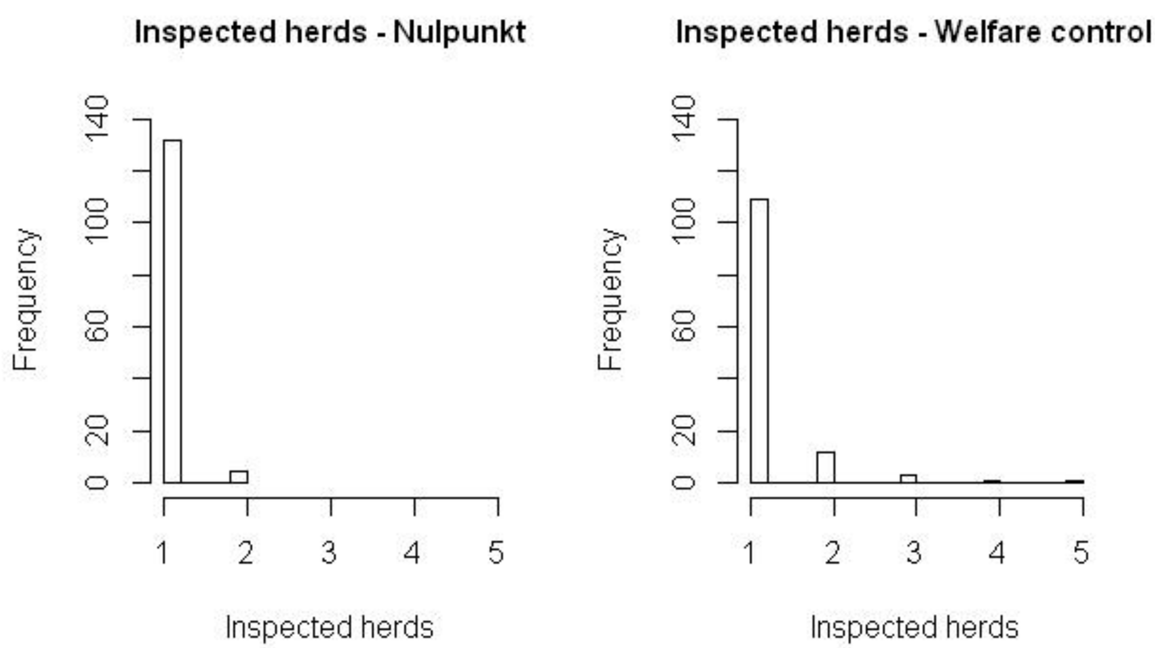

Figure 7.1. The number of inspected herds for the farms in the "nulpunkt" data set and farms in the welfare control data set

The number of violations registered for a farm should be considered as a count variable. It is an ordered variable, because it is better to have no violations than to have 5 violations. We wish to test whether farms that were inspected at more than one herd have different inspection results than farms that were inspected at only one herd. Therefore, we test whether the indicators "total number of violations" and "most severe violation" depend on the number of herds inspected at the farm. This is performed with the non-parametric Mann Whitney U test for ordered categorical variables (see section A.4 in the appendix for further information on this test). Testing for differences in the total number of violations, the null hypothesis is:

H_0: There is no difference in the distribution of the total number of violations between farms with one herd inspected and farms with more than one herd inspected.

H_1: There is a difference.

This is tested for the pooled dataset including both "nulpunkt" data and welfare control data[7]. The test yields a Z-score = -0.295, and a p-value = 0.771 and therefore the null hypothesis cannot be rejected. There is no difference between the distributions when testing for the number of violations.

The indicator "most severe violation" is also an ordered categorical variable. It is clearly an ordered variable, because it is better to have no violations, than to receive an injunction. Therefore, we use the same approach to test whether there is a difference in the distributions of the most severe violation. The null and alternative hypotheses are similar, and so is the result of the test with a Z-score = 0.088 and p-value = 0.943. This means that the null hypothesis cannot be rejected.

Additionally we tested if there is a difference in the distribution of indicators "total number of violations" and "most severe violation" when all herds at the farm were inspected or not. Testing for the indicators "total number of violations" and "most severe violation," the null hypothesis is:

H_0: There is no difference in the distribution of the total number of violations (most severe violation) between farms with all herds inspected and farms with not all herds inspected.

H_1: There is a difference.

The test statistics Z-score = -0.476, and a p-value = 0.635 and Z-score = -0.172, and a p-value = 0.868 for the total number of violations and the most severe violation, respectively. In both cases we fail to reject the null hypotheses. Therefore, it does not cause any significant bias in the data that some farms are tested at more than one herd. The internal consistency in the datasets is therefore not seriously biased due to this problem.

[7] We do not test it within individual samples, because there are only few farms in the "nulpunkt" data that have more than one herd inspected.

7.1.2. Share of Pigs Inspected

A related issue is that some farms have all their pigs inspected, whereas other farms only have a share of their pigs inspected. As discussed in section 5.1.3 this issue is not possible to overcome in the aggregation procedure, and could induce a bias. The non-parametric Mann Whitney U test is used to test whether this affects the results of the inspections. Testing for the total number of violations, the null hypothesis is:

H_0: There is no difference in the distribution of the total number of violations between farms having all their pigs inspected and farms not having all their pigs inspected.

H_1: There is a difference.

This is tested for the pooled dataset of "nulpunkt" data and welfare control data. The test yields a Z-score = 0.378, p-value = 0.707, and therefore the null hypothesis cannot be rejected. The same was tested for the indicator "most severe violation," and the result was similar with Z-score = 0.158, p-value = 0.880[8]. Therefore, the share of inspected pigs (pig units) does not affect the result of the inspection. The assumption underlying the aggregation procedure when not all pigs are inspected does not cause any significant bias to the data.

7.2. Comparing "Nulpunkt" Data and Welfare Control Data

7.2.1. Production Types Inspected

In order to distinguish the technological differences between the different types of pig production we classified pig farmers into four production types: having all types of pigs, only slaughter pigs, piglets and slaughter pigs, or sows and piglets. The distribution of farms with respect to production types is shown in the table 7.1.

Table 7.1. The distribution of production types in the "nulpunkt" data and the welfare control data

Production type	integrated pig producers	specialized slaughter pig producers	farms with small piglets and slaughter pigs	specialised piglet producers	Total
"nulpunkt" data	67	39	20	9	135
welfare control data	84	24	10	6	126
Total	151	66	30	15	261

If the production technology is not the same for the production types, then a difference in the distribution of production types could entail differences in animal welfare. Using Pearson's χ^2 test it is possible to assess

[8] The same hypothesis and indicators were tested within the datasets, and it did not differ from the conclusion for the pooled dataset.

whether the distribution of production types is different between the “nulpunkt” data and the welfare control data (see section A.5 in the appendix for further information on this test).The null hypothesis is:

H_0: There is no difference in the distribution of production types between the “nulpunkt” data and the welfare control data.

H_1: There is a difference.

The test yields a χ^2 statistic = 8.147 and p-value = 0.043 at 3 degrees of freedom, and is therefore significant at the 5 % level. The null hypothesis is rejected, and there is a difference in the distribution of production types in the two datasets. In the following the distributions of the welfare indicators will be tested for the two samples. These will be compared by the production type, so that the difference in the distribution of production types is accounted for.

7.2.2. Animal Welfare Indicators

In the following section we will compare the distributions of the animal welfare indicators for integrated pig producers (“all”) and specialized slaughter pig producers(“only slaughter”), as these two production types account for 82.8 % of total farms in the pooled dataset. There are few observations for specialized piglet producers (“sows + piglets”) and farms with small piglets and slaughter pigs (“piglets + slaughter”).

Table 7.2. Number of observations for production types with and without violations for the “nulpunkt” data and the welfare control data

	Violations	**No violations**	**Total**
Integrated pig producers			
“nulpunkt” data	42	25	67
welfare control data	35	49	84
Specialized slaughter pig producers			
“nulpunkt” data	15	24	39
welfare control data	14	12	26
Farms with small piglets and slaughter pigs			
“nulpunkt” data	11	9	20
welfare control data	4	6	10
Specialized piglet producers			
“nulpunkt” data	2	7	9
welfare control data	3	3	6

7.2.3. AnyViolation

AnyViolation is a categorical variable and therefore Pearson's χ^2 test can be used to test whether there is a difference between the distribution of farms having violations in the "nulpunkt" data and the welfare control data. Testing for the indicator AnyViolation the null hypothesis is:

H_0: There is no difference in the proportion of farms with violations between the "nulpunkt" data and the welfare control data for integrated pig producers.

H_1: There is a difference.

The result of the test provides an X-squared = 6.59 with 1 degree of freedom and a p-value = 0.01. The null hypothesis is therefore rejected at the 5 % significance level, and so there is a difference in whether or not farms were in violation of the animal welfare legislation in the two datasets for integrated pig producers. The same hypotheses are tested for specialized slaughter pig producers and gives X-squared = 1.49 with 1 degree of freedom and a p-value = 0.22. The null hypothesis can therefore not be rejected and there is no difference in the distribution of farms having violations for specialized slaughter pig producers. Producers having all pig types account for 58 % of all observations, and therefore there is a difference for a substantial part of the observations in the pooled sample.

7.2.4. Total Number of Violations

Figure 7.2 provides an illustration of the distribution of the number of violations in the two datasets.

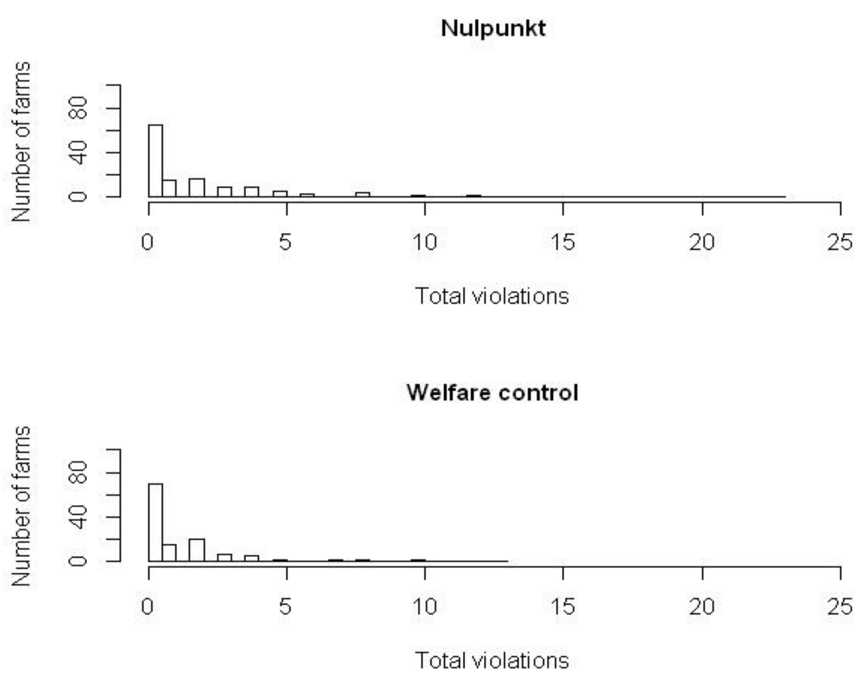

Figure 7.2. Number of farms and total number of violations in "nulpunkt" data and welfare control data

From the figure 7.2 it can be seen that the right tail of the distribution is longer for the “nulpunkt” data than for the welfare control data. So, more farms have several violations in the “nulpunkt” data set compared to the welfare control data set. Looking at the spread of the total number of violations for integrated pig producers shows a clearer image of the differences in distributions (see figure 7.3). It can be seen that much of the difference in the total number of violations is for integrated pig producers.

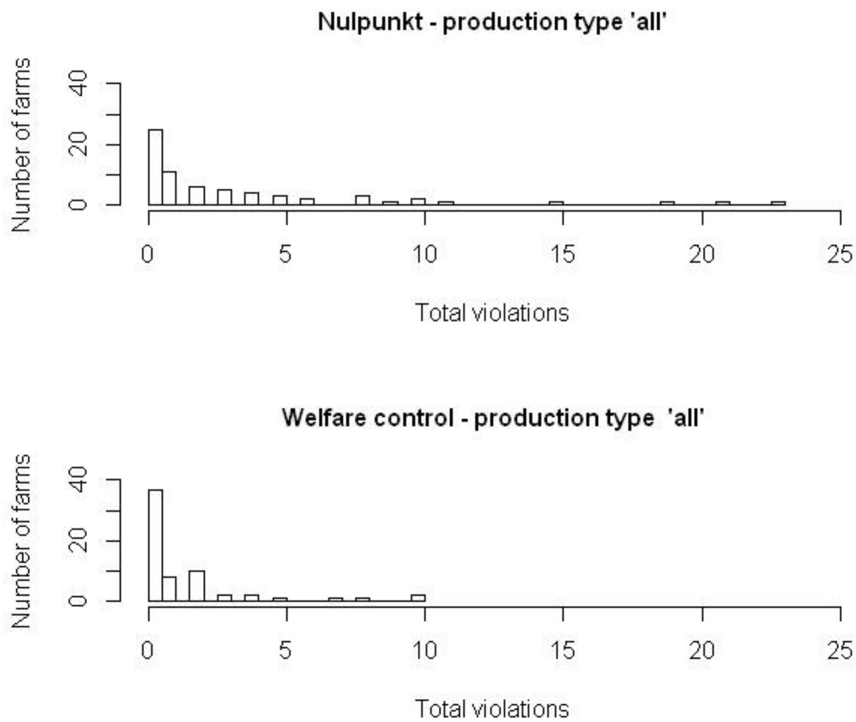

Figure 7.3. Number of integrated pig producers and total number of violations in the “nulpunkt” data set and the welfare control data set

The non-parametric Mann Whitney U test is used to test whether there is a difference in the distributions. Testing for differences in the total number of violations the null hypothesis is:

H_0: There is no difference in the distribution of the number of violations for integrated pig producers between the “nulpunkt” data and the welfare control data.

H_1: There is a difference.

The test results in a Z-score = 2.97 and a corresponding p-value = 0.003. The null hypothesis can therefore be rejected at the 5 % significance level. There is a difference in the distributions of the total number of violations for integrated pig producers between the two data sets. From the histograms in figure 7.4 it can be seen that there are no big differences between the two different data sets of the specialized slaughter pig producers. Testing the same hypotheses for the specialized slaughter pig producers, the non-parametric Mann Whitney U test yields a Z-score = -1.141, p-value = 0.257 and the null hypothesis can therefore not be rejected. There are no differences in the distribution of the total number of violations for specialized slaughter pig producers between the "nulpunkt" data and the welfare control data.

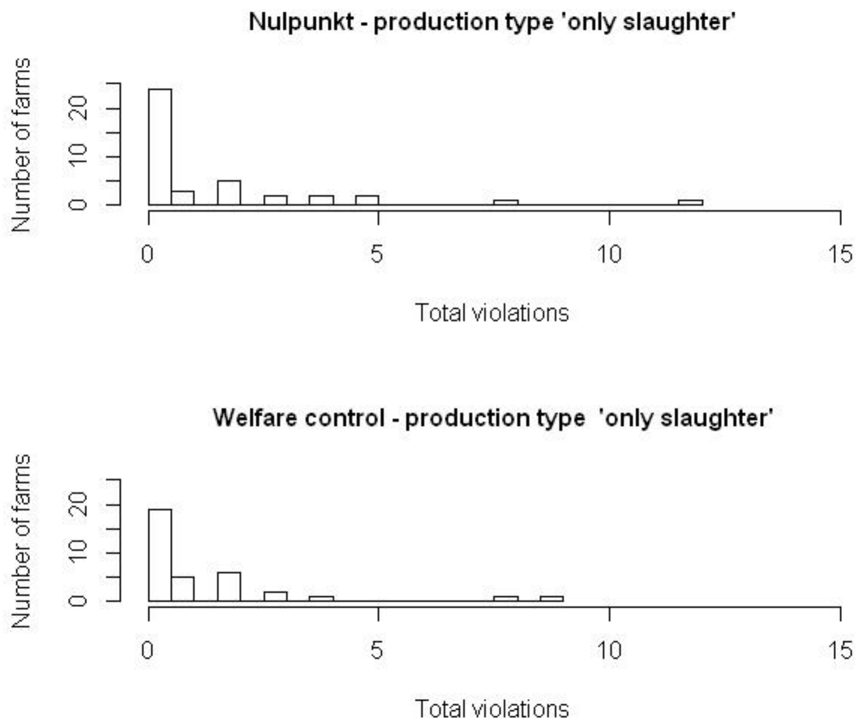

Figure 7.4. Number of specialized slaughter pig producers and the total number of violations in the "nulpunkt" data set and the welfare control data set

7.2.5. Most Severe Violation

The indicator "most severe violation" is an ordered categorical variable, and therefore the Mann-Whitney U test can be applied for testing the distribution between the datasets. As before the null hypothesis is:

H_0: There is no difference in the distribution of the most severe violations for integrated pig producers between the "nulpunkt" data and the welfare control data.

H_1: There is a difference.

The result yields a Z-score = 2.696 and a p-value = 0.007 and therefore the null hypothesis is rejected at the 5 % significance level. Testing the same hypothesis for specialized slaughter pig producers yields a Z-score =

-1.059 and p-value = 0.305 and so the null hypothesis cannot be rejected. Thus, there are no differences between the datasets. Figure 7.5 illustrates the distributions of the most severe violations for all the production types.

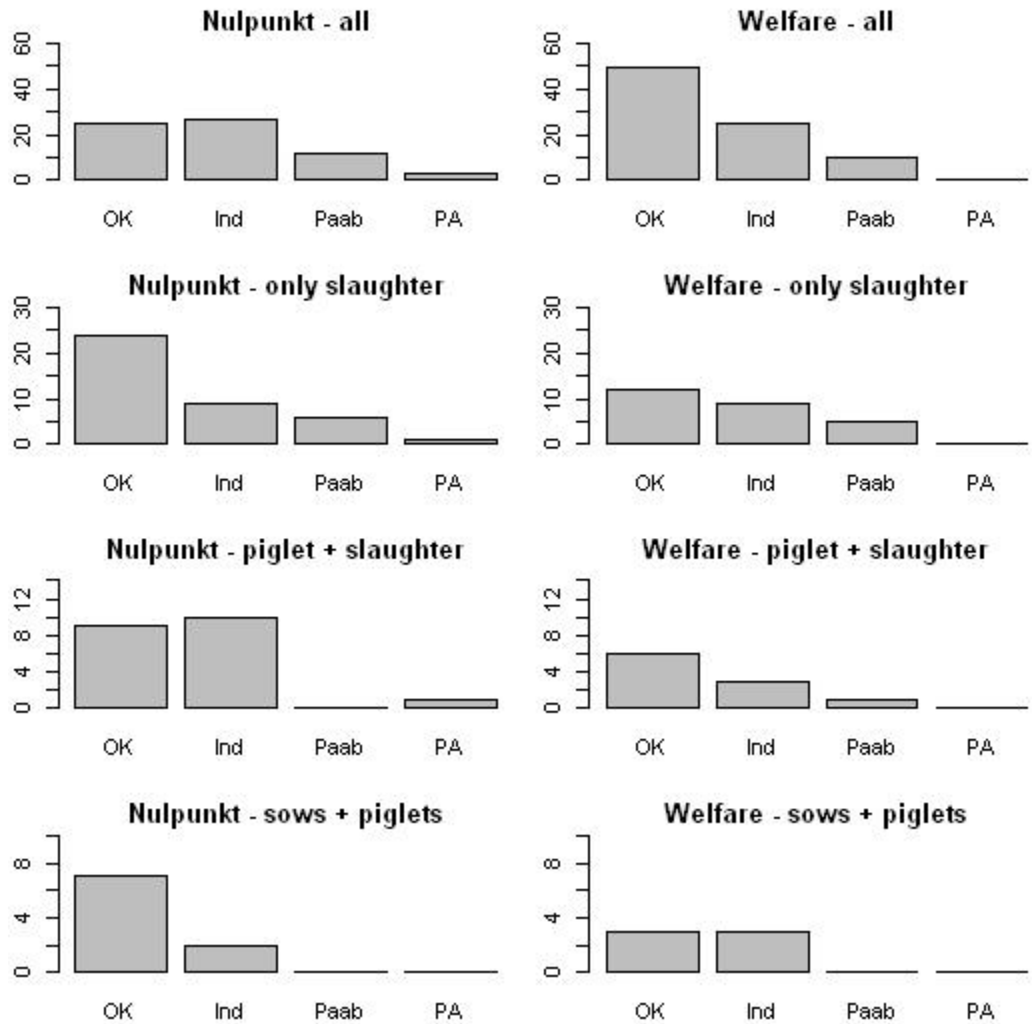

Figure 7.5. Number of farms and the most severe violations for different production types in the "nulpunkt" data and the welfare control data. The x-axis shows the most severe violations. These are "OK"→ no violation, "Ind" → admonition, "Paab" → injunction, "PA" → police report

Besides the results from the statistical tests the samples are also different because some police reports have been excluded in the welfare control data set before we received the data from the Danish AgriFish Agency. This causes a bias to this dataset, because an unknown number of farms with the most severe violation "police report" are not included. Only police reports from the farms where the legal conviction are already finished are included in the welfare control data set. For these farms the particular checkpoint that was violated or the number of violations of the farmer are unknown. Therefore only the indicator “most severe violation” can be used without adding further bias to the indicators of animal welfare.

7.3. Summary

This section shows that there are differences between the two datasets. First, the number of herds inspected per farm is different between the “nulpunkt” data and the welfare control data, but the number of herds inspected does not affect the indicators of welfare. So, the aggregation method is assumed not to cause any significant bias. The distribution of the production types are different between the “nulpunkt” data and the welfare control data. In the “nulpunkt” data, there are fewer farms classified as integrated pig producers than in the welfare control data, but they tend to violate the animal welfare regulations more frequently and they also have more violations than the farms in the welfare control data. Furthermore, integrated pig producers have more severe violations in the “nulpunkt” data than the integrated pig producers in the welfare control data. Integrated pig producers account for 58 % of the observations in the pooled dataset[9]. The differences in the distributions of the two samples, and the number of observations involved indicate that the “nulpunkt” data and the welfare control data should not be pooled to one dataset. As already mentioned in section 3.3,the “nulpunkt” data set is based on a random sample, while the welfare control data set is based on a non-random sample, and some police reports are not included in the welfare control data set. Therefore, we choose to focus our further analysis solely on the “nulpunkt” data in order to avoid biased results due to non-random sampling, missing police reports and possibly less strict inspections in the welfare control data.

[9] Though not reported here there were no significant differences for the production types “piglets + slaughter” and “sows + piglets”.

8. Animal Welfare and Economics

This section will present and analyze the relationship between economic variables and animal welfare indicators based on the “nulpunkt” dataset. As before we focus on integrated pig producers and specialized slaughter pig producers as they account for most observations in the dataset.

The analysis of the relationship between animal welfare and economic outcome is restricted to farms were the revenues from pig production is at least 66% of total revenues from animal production. In the following we use several statistical tests. The overview of the main results is presented in appendix B.

8.1. Total Number of Pig Units and Animal Welfare

Winter *et al.* (1998) argue that the structural adjustment process in agriculture has contributed to declining farm animal welfare through larger farms and fewer mixed farms. It is possible to investigate the relationship between animal welfare and the number of pig units at farms, and thereby whether size is correlated with animal welfare management. This will be done for integrated pig producers and specialized slaughter pig producers. In section 3.1 it was stated that the nature of the inspection could cause larger farms to have more violations. In Lassen *et al.* (2012) a farmer mentions that having a large farm increases the likelihood of making minor mistakes with regards to the animal welfare legislation. On the other hand, larger farms might also be more professionally managed and therefore have few violations.

Several studies within the economic literature connect herd size and animal welfare. Results in Lawson *et al.* (2004a) show that larger dairy herds are more technical efficient, although they have higher occurrence of treated diseases. An opposite result was found in Barnes *et al.* (2011) who show that farms with lower levels of lameness tend to have lower average number of cows within the herd. Stott *et al.* (2012) find that in extensive sheep farming flock size is not correlated with animal welfare. Results on this matter are therefore mixed. The following section will study this in the case of pig production.

The distribution of the number of pigs for different production types in the “nulpunkt” data set is presented in the figure 8.1. It shows a large spread in the distribution between farms and between production types.

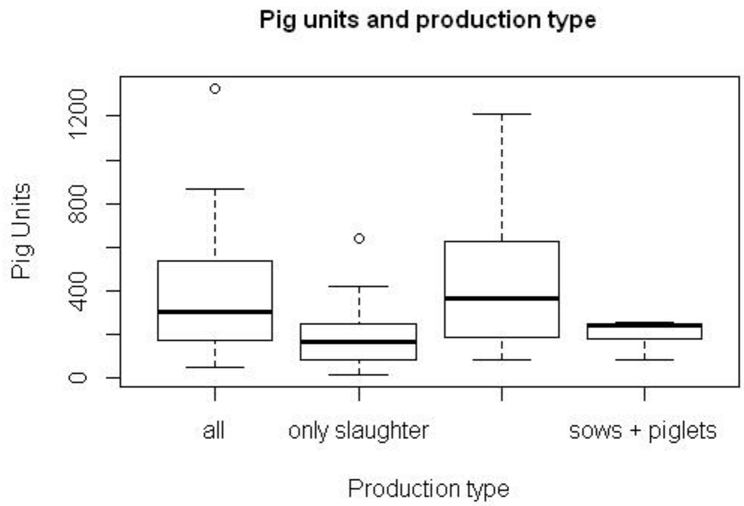

Figure 8.1. Production types and the number of pig units

8.1.1. Total Number of Violations

Figure 8.2.below illustrates the relationship between the indicator for the total number of violations and the number of pigs units at the farms.

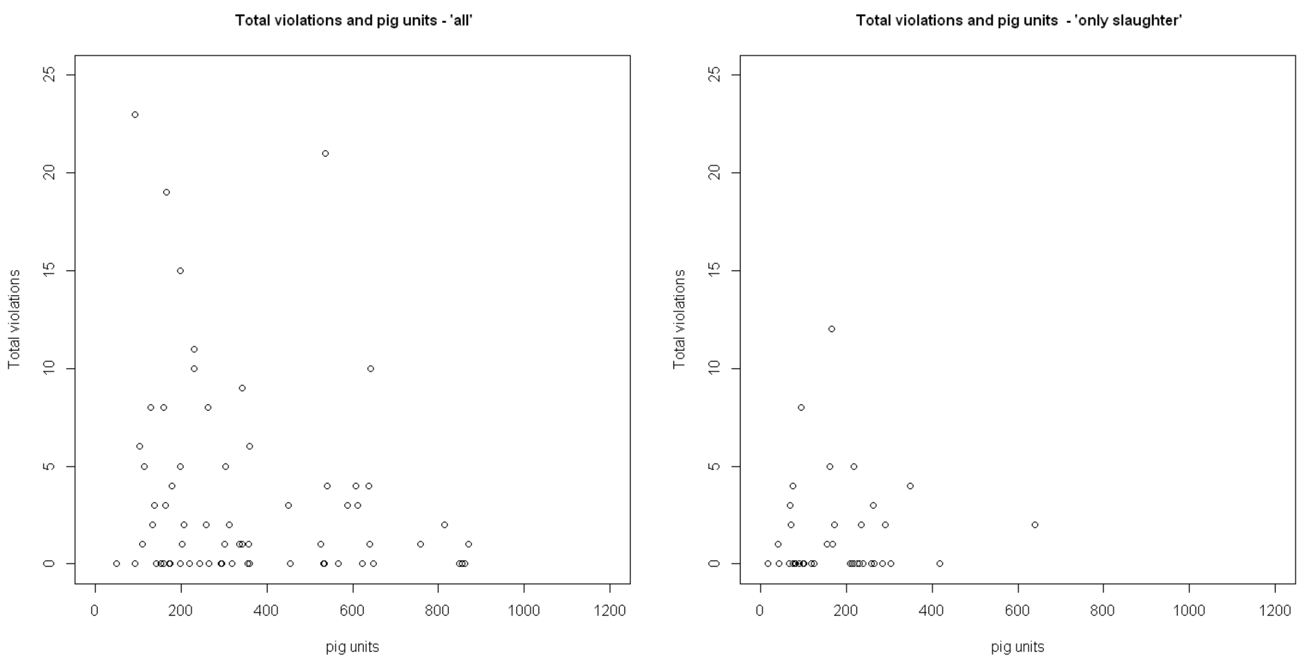

Figure 8.2. Total number of violations and the number of pig units for integrated pig producers and specialised slaughter pig producers

From the figure 8.2 it is difficult to observe any relationship between the total number of violations and the number of pig units. Small farms have both no violations and many violations, and the same is true for larger farms. A negative tendency could be depicted for integrated pig producers as larger farms have fewer violations. Pearson's correlation test can be used to test for correlation between two variables. The null hypothesis is:

H_0: The correlation between the total number of violations and the number of pig units for integrated pig producers is equal to zero.

H_1: The correlation is not equal to zero.

The correlation is -0.19 and testing this result with a t-test gives a t-value = -1.54 at 65 degrees of freedom, which has the p-value = 0.13. The null hypothesis cannot be rejected, and so there is no correlation between the total number of violations and the number of pig units for integrated pig producers. There is no significant correlation for specialized slaughter pig producers at any significance level.

8.1.2. Most Severe Violation

Figure 8.3 shows the number of pig units in the groups of the most severe violations reported for integrated pig producers and specialized slaughter pig producers. The number of pig units per farm does not seem to vary significantly with the indicator "most severe violation" for either of the production types. The median is almost the same, and the so are the variances. It can be seen for integrated pig producers that farmers who are reported to the police for violations tend to have fewer pigs, but this is only true for 3 observations, so this could be by coincidence and nothing can be generalized from this.

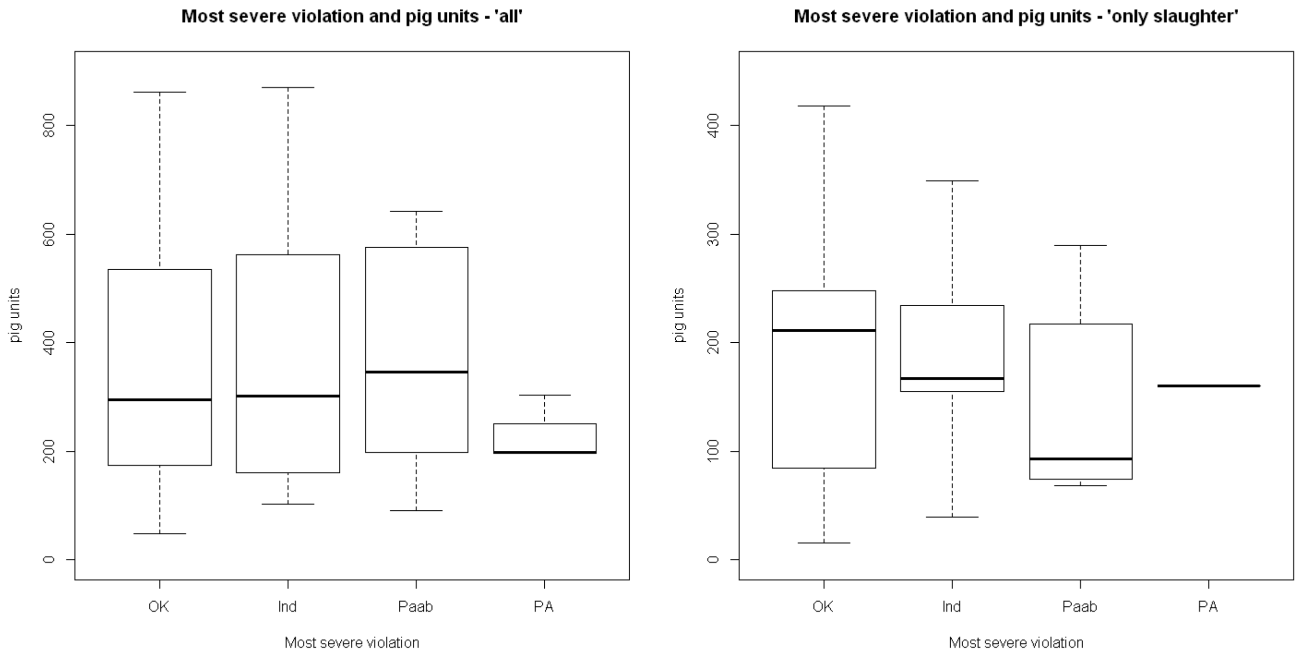

Figure 8.3. The most severe violation and the number of pig units for integrated pig producers and specialized slaughter pig producers[10]

8.1.3. AnyViolation

Instead the difference between farms with and without violations for the two production types is tested with Welch's two-sample t-test (see section A.1 in the appendix for further information on this test). Testing with regards to the indicator AnyViolation the hypotheses to be tested are:

H_0: There is no difference in the average number of pig units for integrated pig producers with or without violations of the animal welfare legislation.

H_1: There is a difference.

The null hypothesis cannot be rejected for integrated pig producers (t = 0.077, df = 53.57, p-value = 0.938), so there is no difference in the average number of pig units between farms with or without violations. It is also tested for specialized slaughter pig producers and this gives a t-value = 0.321 at 32.7 degrees of freedom and p-value 0.75. Therefore, for specialized slaughter pig producers the null hypothesis also cannot be rejected.

[10]In this figure an outlier for the production type "all" was excluded to make the boxplot easier to read.

8.2. Gross Margin per Pig Unit and Animal Welfare

Animal welfare could potentially affect gross margin in several direct and indirect ways. The central items in the calculation of the gross margin are feed costs, medicine and veterinary costs, and revenue from pig production. In section 2 it was described that animal welfare is likely to be related to input use, veterinary practice, and well-conditioned pigs are likely to earn larger revenues. The correlation between gross margins and animal welfare can go both ways. Farms having large gross margins are likely to be good managers, which could imply that they have good welfare management. The opposite could also be true. This was hypothesized in the figure 3.1, which illustrated that decreasing animal welfare could increase livestock productivity and through this gross margin.

Figure 8.4 shows the distribution of gross margins per pig unit for the different production types.

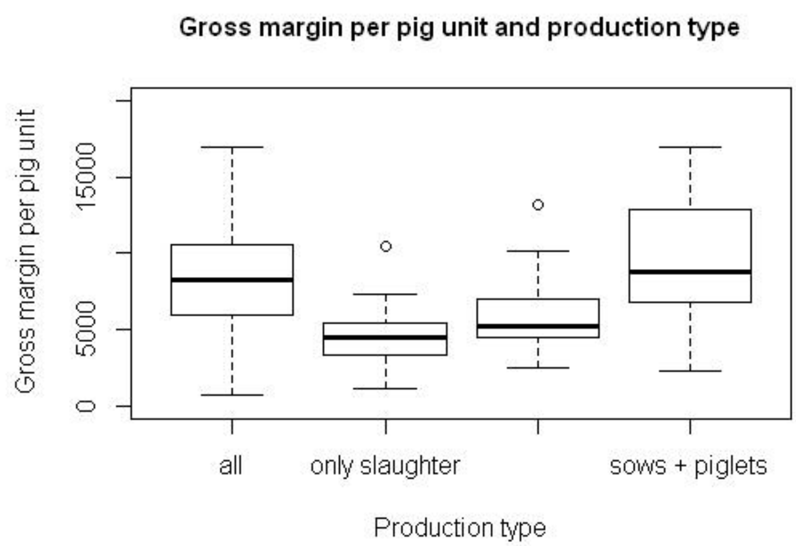

Figure 8.4. Gross margin per pig unit (DKK) and production types[11]

According to the Figure 8.4 there are significant differences in gross margins between production types, but also between farms of the same production type.

A correlation test shows a significant and positive relationship between gross margin per pig unit and the total number of pig units for integrated pig producers. There is no significant correlation in the case of specialized slaughter pig producers.

[11]In this figure an outlier for the production type "all" was excluded to make the boxplot easier to read.

8.2.1. Total Number of Violations

Figure 8.5 shows the variation between gross margin per pig unit and the total number of violations. For integrated pig producers a correlation test shows a correlation coefficient of -0.24 with 65 degrees of freedom and p-value = 0.052. The correlation between gross margin per pig unit and the total number of violations is therefore negative and significant at the 10 % level. For specialized slaughter pig producers the correlation coefficient is -0.20 with 37 degrees of freedom and the p-value is 0.21. Therefore there is no significant correlation between gross margin per pig unit and the total number of violations for specialized slaughter pig producers.

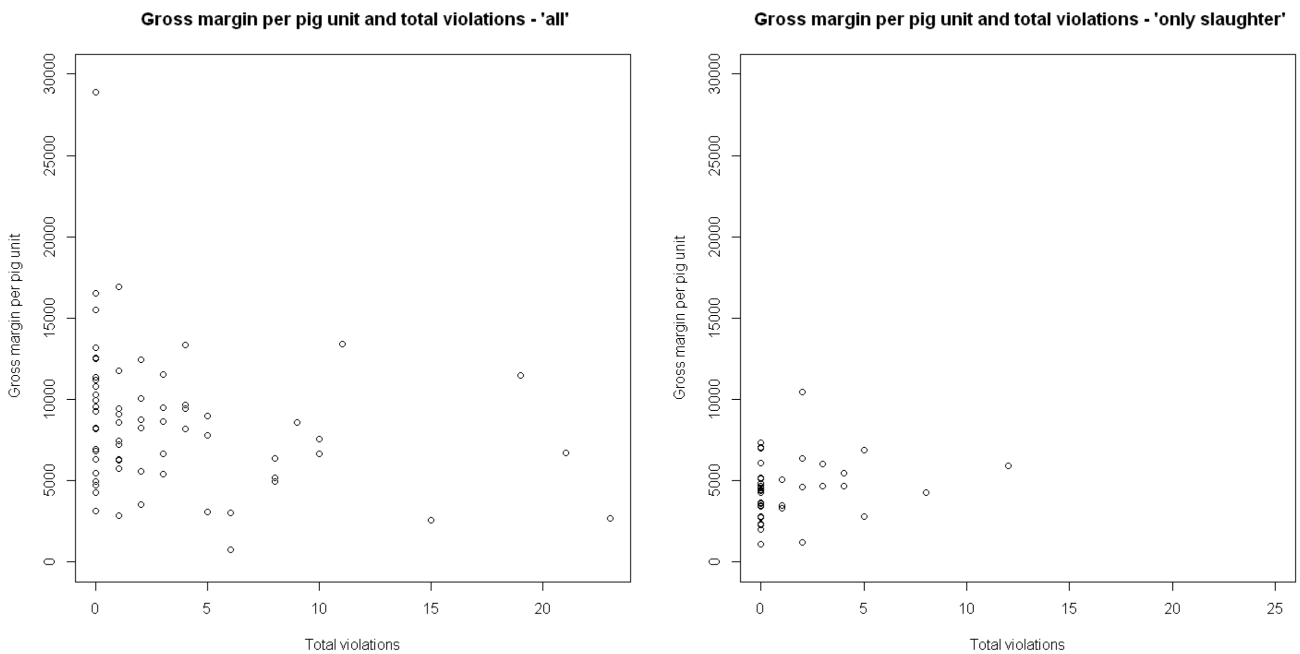

Figure 8.5. Gross margin per pig unit (DKK) and the total number of violations for integrated pig producers and specialized slaughter pig producers

8.2.2. Most Severe Violation

The indicator "most severe violation" suffers from having too few observations in the different groups of sanctions (see figure 8.6). The category police reports ("PA") only has three and one observations for integrated pig producers and specialized slaughter pig producers, respectively.

There is some variation between the gross margins per pig unit between groups, but the tendencies are unclear. A one-way ANOVA can be used to test differences in means between groups (see section A.2. in the appendix for further information on this test).

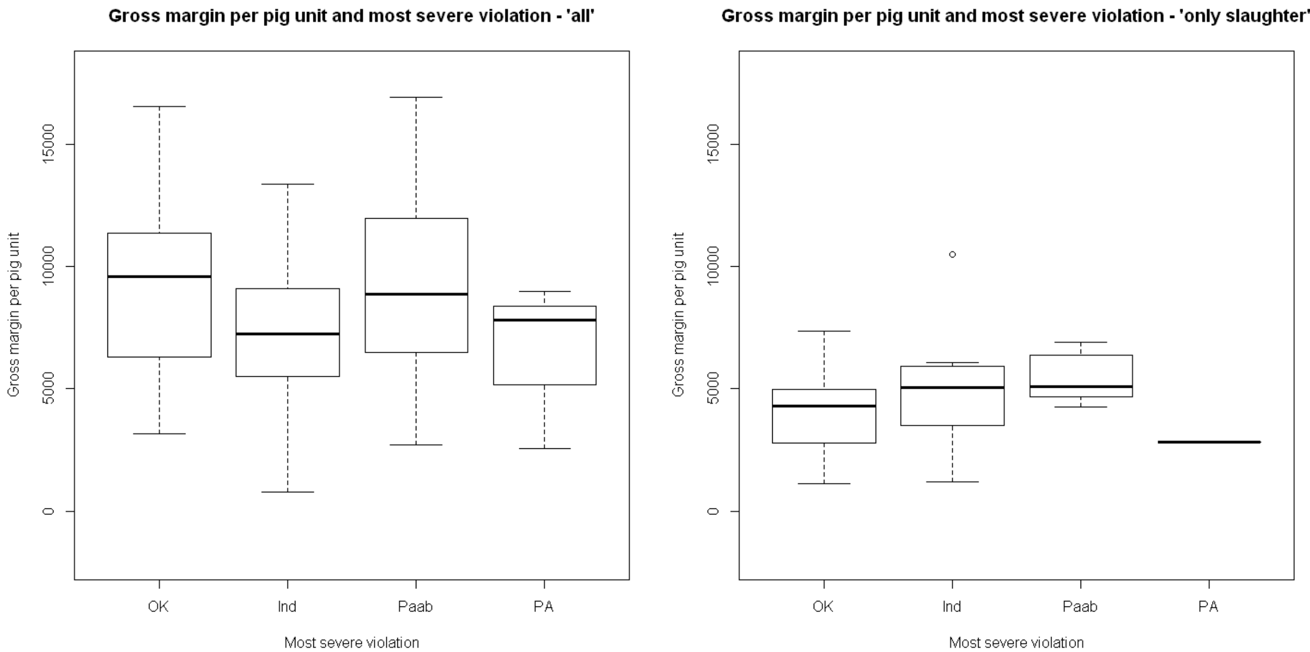

Figure 8.6. Gross margin per pig unit (DKK) and the most severe violations for integrated pig producers and specialized slaughter pig producers

We test for significant differences in the gross margin per pig unit between farms with different most severe violations for integrated pig producers and specialized slaughter pig producers:

H_0: There is no difference in the average gross margin per pig unit for farms having different most severe violations for integrated pig producers (specialized slaughter pig producers).

H_1: There is a difference.

Performing the test gives an F-value= 2.48 and a p-value = 0.07. The null hypothesis is rejected at the 10 % significance level, and therefore there is a difference in gross margins. The ANOVA does not provide information on the differences between gross margins, so a Tukey's test of multiple comparisons is used. This test compares the average gross margin per pig unit of all possible pair wise combinations of groups. The difference between farms having no violations and farms having an admonition as the most severe violation is significant at the 10 % level. On average the gross margin per pig unit for farms with no violations was 9,925 DKK and 7,070 DKK for farms an admonition. Notably, there is no statistical difference between farms with no violations and farms with an injunction ("Paab") as the most severe violation. The one-way ANOVA for specialized slaughter pig producers does not show any significant differences in gross margins per pig unit and the most severe violation.

8.2.3. AnyViolation

In order to see if a simpler comparison shows any differences we compare farms with and without violations in the figures below.

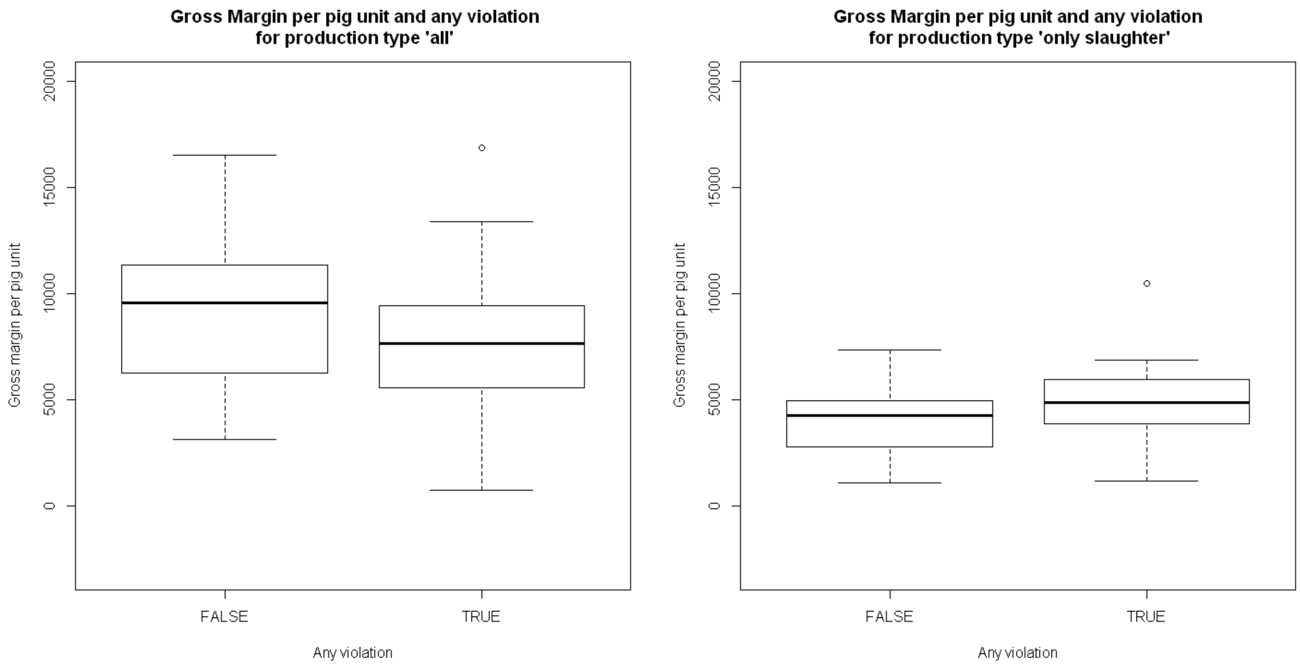

Figure 8.7. Gross margin per pig unit (DKK) and farms with and without violations for integrated pig producers and specialized slaughter pig producers

T-tests show that there is a significant difference in gross margins per pig unit at the 10 % level for integrated pig producers (t = 1.914, df = 35.85, p-value = 0.064), whereas there are is no significant difference for specialized slaughter pig producers (t = -1.359, df = 24.333, p-value = 0.187).

8.2.4. Rooting Materials and Sick Animals

The relationship between gross margin per pig unit for farms violating checklist criteria on rooting and playing materials and sick animals are shown in figure 8.8 and 8.9. It is interesting to note that for integrated pig producers the gross margins are larger for farms with no violations, whereas the opposite is true for specialized slaughter pig producers. For the integrated pig producers the differences between farms with violations and farms without violations are statistically significant at the 5 % levels for rooting materials (t = 2.878, df = 41.255, p-value = 0.006), but is not significant for sick animals (t = 1.322, df = 48.852, p-value = 0.192). For specialized slaughter pig producers there were no statistically significant differences.

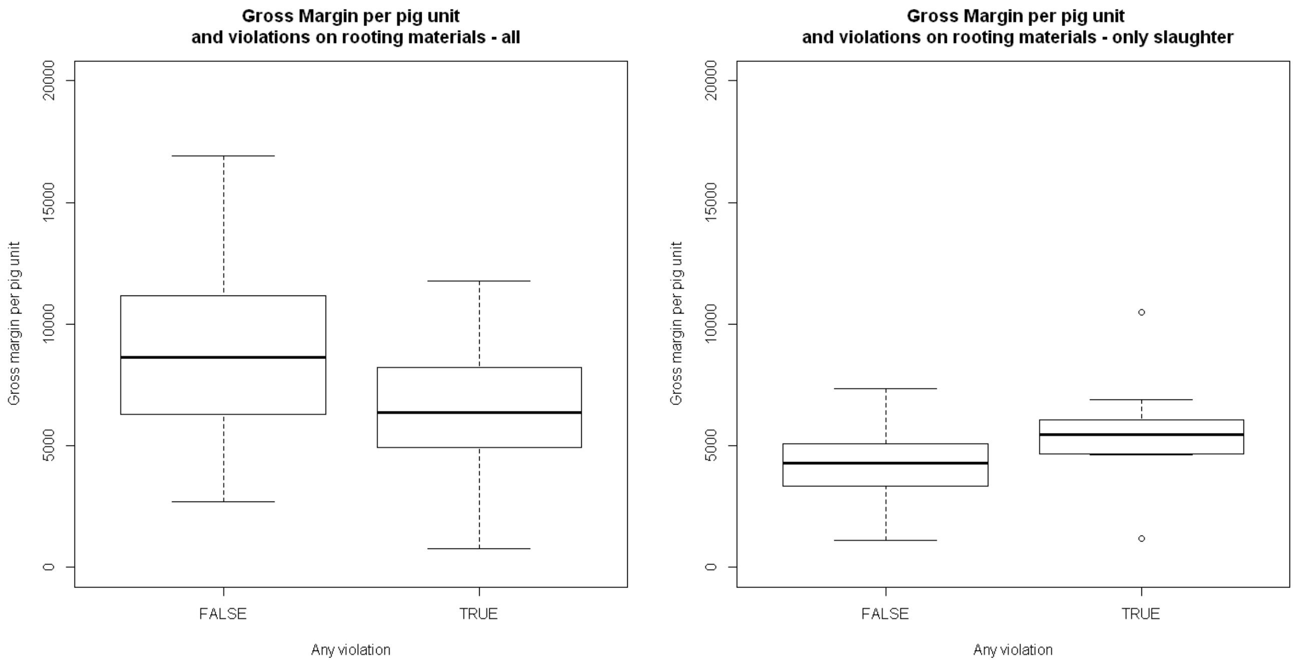

Figure 8.8. Gross margin per pig unit (DKK) and farms with and without violations concerning rooting materials for integrated pig prodders and specialized slaughter pig producers

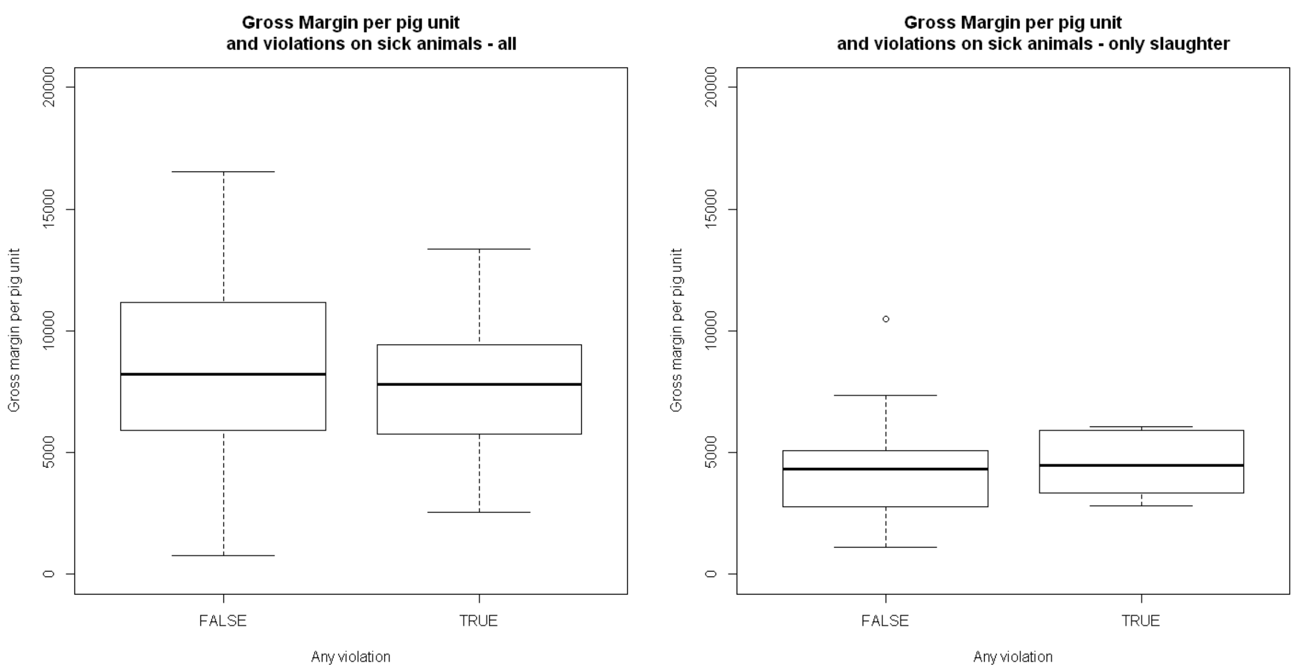

Figure 8.9. Gross margin per pig unit (DKK) and farms with and without violations concerning sick animals for integrated pig prodders and specialized slaughter pig producers

8.3. Medicine and Veterinary Costs per Pig Unit and Animal Welfare

Medicine and veterinary costs are closely connected to the health management of pigs. It is therefore relevant to study the correlation with animal welfare. The measure of medicine and veterinary costs per pig unit is difficult to assess with respect to animal welfare, because high expenses could be both good and bad for the welfare. Significant use of veterinarians and medicine could indicate that the farmer is bad at managing animals' health, or that the farmer is very attentive towards the animals.

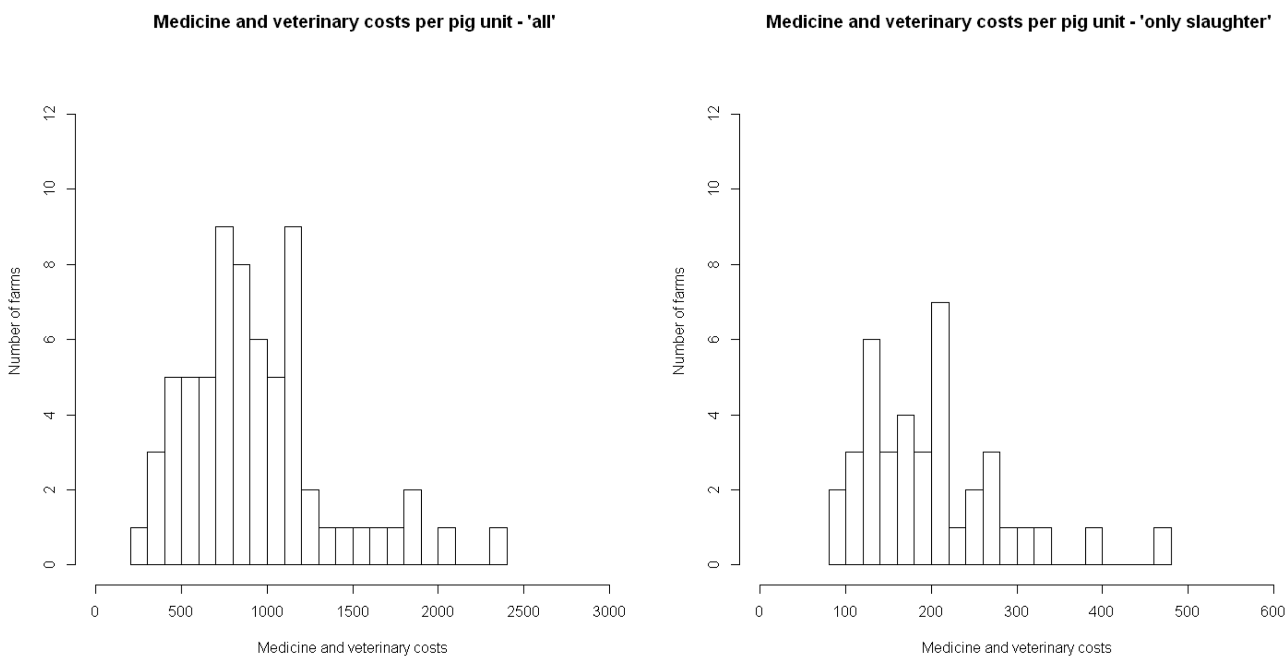

Figure 8.10. Medicine and veterinary costs per pig unit (DKK) for integrated pig producers and specialized slaughter pig producers

Figure 8.10 shows that the distribution of veterinary and medicine costs vary between production types. The study by van der Fels-Klerx *et al.* (2011) confirms a significant difference in the use of antibiotics between slaughter pig producers and farms with sow production. They also find a large between-farm variation in the use of antibiotics, and suggest that differences are due to hygiene status, degree of preventive use, and treatment decisions by the farmer or veterinarian. The between-farm differences are constant over time, and the variation in usage therefore doesn't change.

The variation in veterinary and medicine costs per pig unit does not seem to be affected by the number of pigs at the farm, which can be seen in the figure 8.11. The fact that the costs per pig unit is not correlated with the number of pigs produced at the farm indicates that the hygiene status and/or degree of preventive use do not depend on the size of farm either.

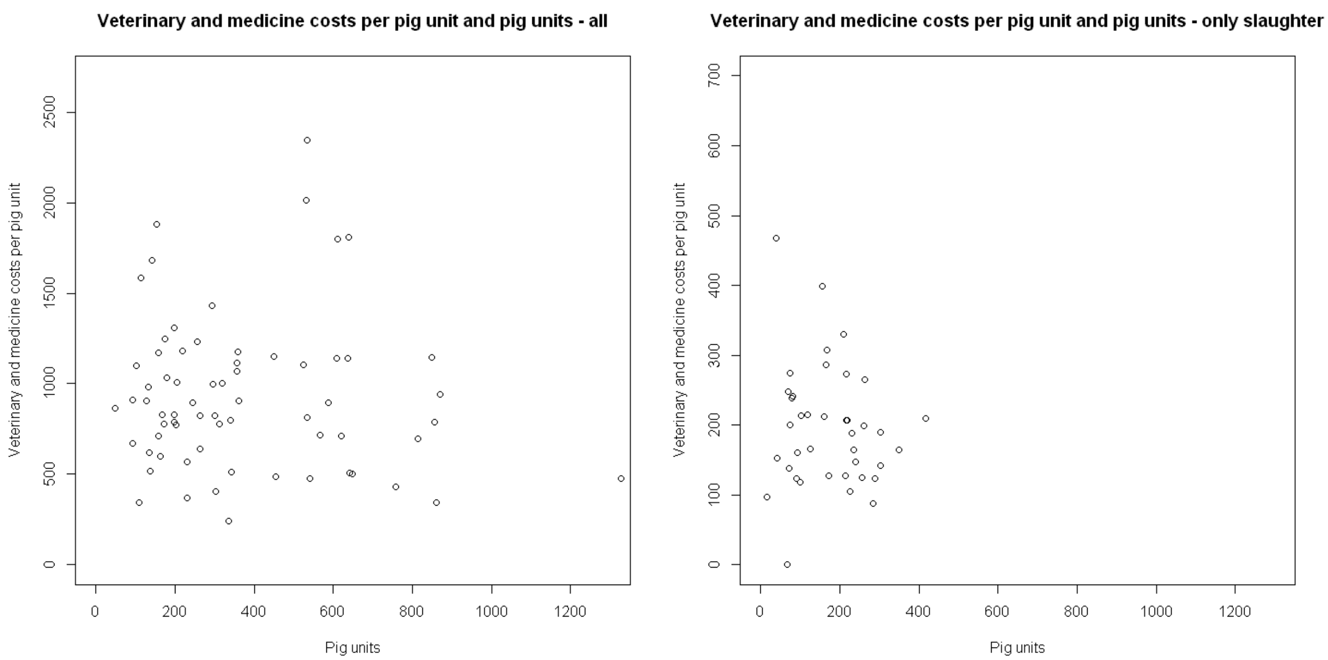

Figure 8.11.Medicine and veterinary costs per pig unit (DKK) and pig units for integrated pig producers and specialized slaughter pig producers

8.3.1. Total Number of Violations

The relationship between the total number of violations and medicine and veterinary costs per pig unit is shown in the figure 8.12. It does not reveal any obvious relationships.

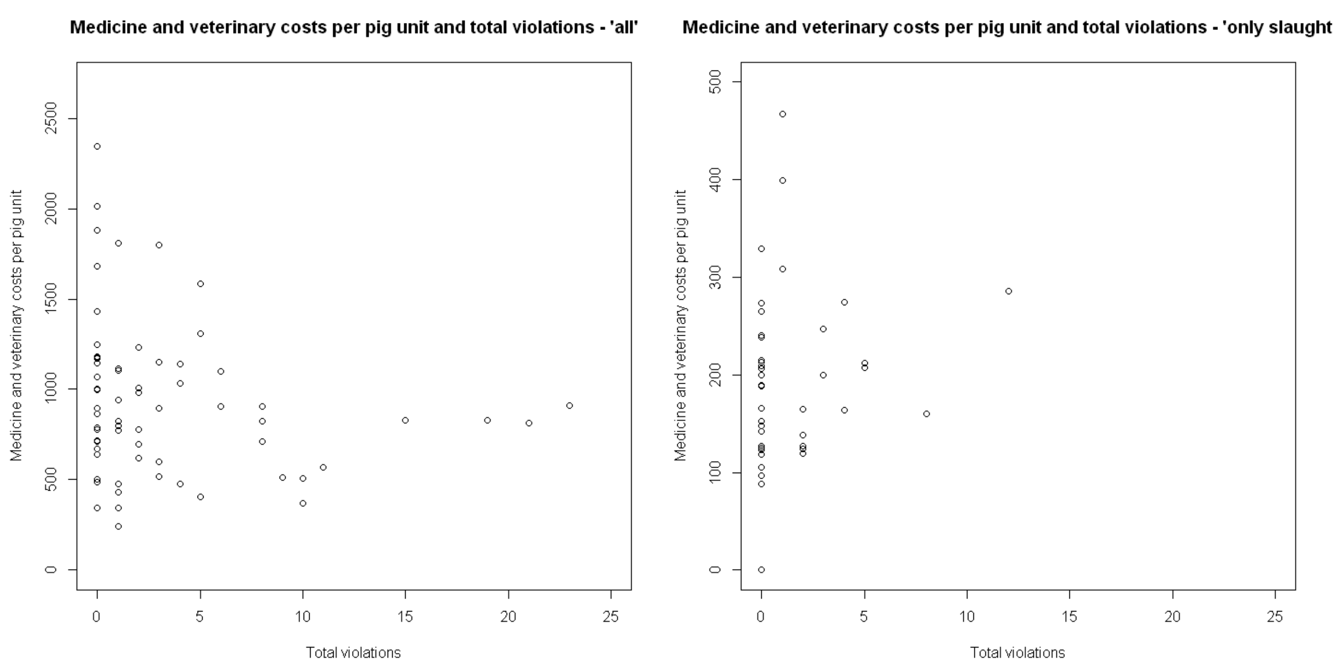

Figure 8.12. Medicine and veterinary costs per pig unit (DKK) and the total number of violations for integrated pig producers and specialized slaughter pig producers

8.3.2. Most Severe Violation

A one-way ANOVA test shows that there are no differences in veterinary and medicine costs per pig unit between the most severe violations at the 10 % level for integrated pig producers. Testing this for specialized slaughter pig producers showed that there is a difference in medicine and veterinary costs per pig unit (F-value= 2.72 with p-value = 0.06). Specialisedslaughter pig producers in the group with no violations had medicine and veterinary costs per pig unit of 173 DKK on average, whereas producers having an admonition as the most severe violation had costs of 232 DKK on average. This difference in medicine and veterinary costs per pig unit is significant at the 10 % level.

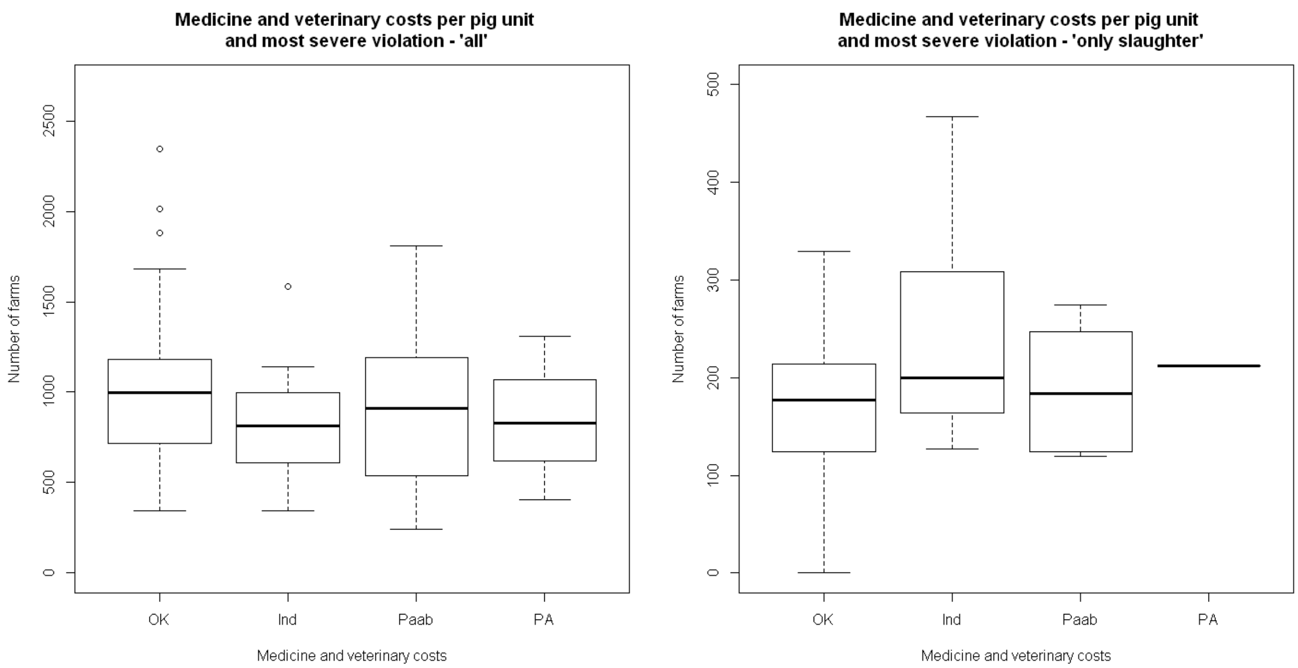

Figure 8.13. Medicine and veterinary costs per pig unit (DKK) and the most severe violations for integrated pig producers and specialized slaughter pig producers

8.3.3. AnyViolation

It can be seen from the figure 8.13 above that for integrated pig producers, farmers with no violations seem to have higher medicine and veterinary costs than farmers with violations. Therefore, we separate farms with and without violations in figure 8.14.

A two-sample t-test analyzing whether there is a difference in means for farmers with and without violations shows a difference at the 10 % significance level for integrated pig producers (t = 1.796, df = 39.412, p-value = 0.080). Farmers with no violations have medicine and veterinary costs per pig unit of 1,061 DKK on average, whereas farmers with violations have costs of 857 DKK on average. However, for specialized slaughter pig producers the opposite tendency was significant at the 10 % level. Farms with no violations had mean medicine and veterinary costs of 173 DKK, and farmers with violations had mean costs of 232 DKK. As mentioned, causality cannot be determined based on this and the direction of the relationship between medicine and veterinary costs per pig unit and animal welfare seems to differ depending on the production type.

The relationship between the checklist measures concerning rooting materials and sick animals could be argued to be the indicators most related to medicine and veterinary costs, because they indirectly concern the activity levels and health status of animals.

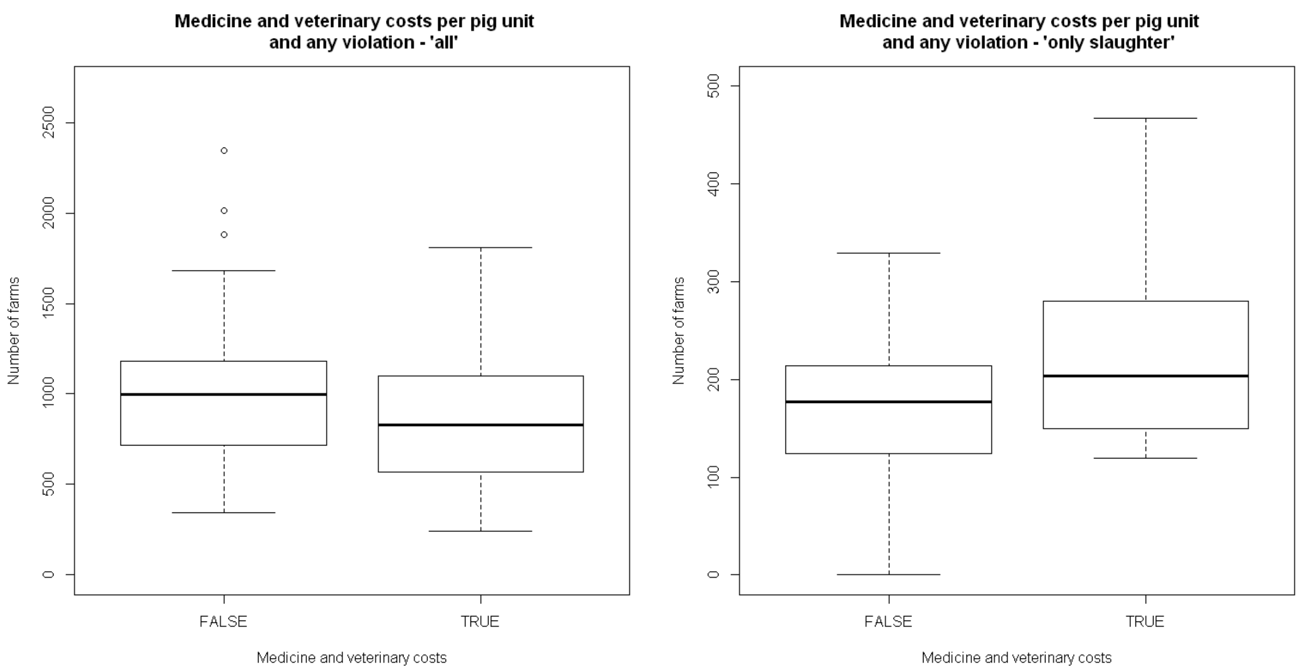

Figure 8.14. Medicine and veterinary costs per pig unit (DKK) and farms with and without violations for integrated pig producers and specialized slaughter pig producers

8.3.4. Rooting Materials

The welfare indicator for rooting and playing materials is tested against medicine and veterinary costs per pig unit for integrated pig producers and specialized slaughter pig producers, respectively. The effect is statistically significant at the 10 % level for integrated pig producers (t-test statistics is equal to t = 1.788 with p-value = 0.082). The average costs for farms with no violations is 980 DKK and farms with violations have average costs of 795 DKK. There is no statistical difference for specialized slaughter pig producers (t-test statistics is equal to t = 0.036 with p-value = 0.972).

8.3.5. Sick Animals

A t-test shows that there is no difference in medicine and veterinary cost per pig unit between farms with and without violations for integrated pig producers.

For specialized slaughter pig producers there is also a difference in average medicine and veterinary cost per pig unit between farms with and without violations. This difference is statistically significant at the 10 % level (t-test statistics is equal to t = -2.027 with p-value = 0.083). Farms with no violations have average medicine and veterinary costs of 184 DKK and farms with violations have average costs of 261 DKK.

In general, the association between the welfare indicators and medicine and veterinary costs per pig unit is unclear. Integrated pig producers without violations seem however to have higher medicine and veterinary costs than integrated pig producers with violations, whereas the opposite is true for specialized slaughter pig producers.

8.4. Revenue from pig production per pig unit and Animal Welfare

8.4.1. Total Number of Violations

The relationship between the total number of violations and revenue from pig production per pig unit is shown in the figure 8.15.

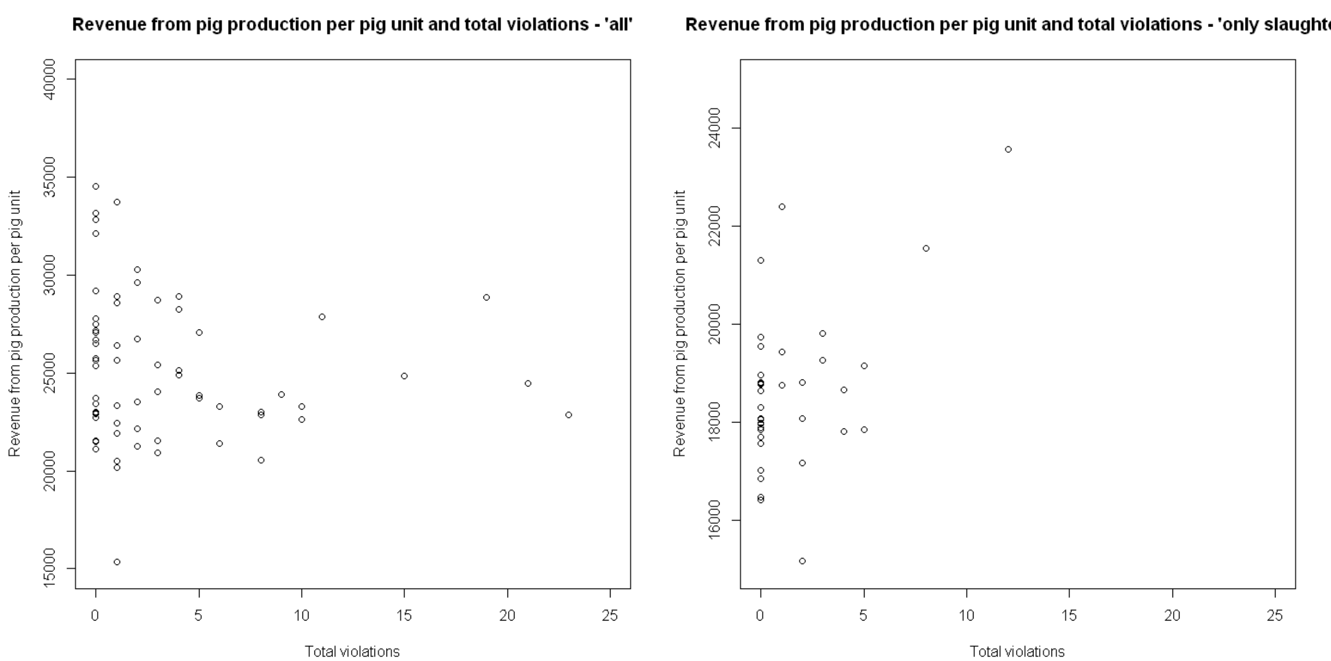

Figure 8.15. Revenue from pig production per pig unit (DKK) and the total number of violations for integrated pig producers and specialized slaughter pig producers

Pearson' correlation test shows that there is no significant correlation for integrated pig producers (t-test statistics is equal to t = -1.044 with p-value = 0.300) and positive, significant correlation for specialized slaughter pig producers (t-test statistics is equal to t = 3.778 with p-value = 0.001).

8.4.2. Most Severe Violation

The distribution of the indicator "most severe violation" is presented in the figure 8.16.

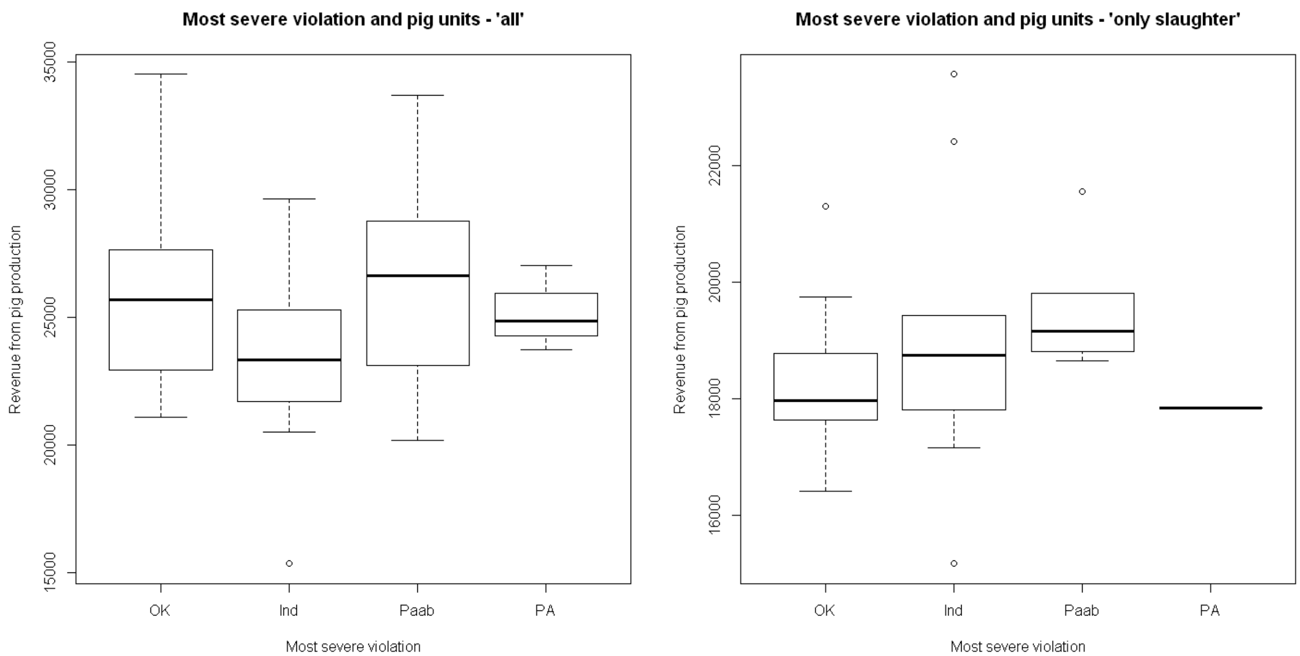

Figure 8.16. Revenue from pig production per pig unit (DKK) and most severe violation for integrated pig producers and specialized slaughter pig producers

We use one-way ANOVA to test differences in means between groups. Testing the difference for integrated pig producers and specialized slaughter pig producers:

H_0: There is no difference in the average gross margin per pig unit for farms having different most severe violation for integrated pig producers (specialized slaughter pig producers).

H_1: There is a difference.

The ANOVA indicates a statistical difference only for integrated pig producers. The F statistic has a F-value= 2.61, and a p-value = 0.06, therefore the null hypothesis is rejected at the 10 % significance level. Hence, there is a difference in revenue from pig production. To further investigate the differences we use a Tukey's test of multiple comparisons. The difference between farms having no violations and farms having an admonition as the most severe violation is significant at the 10 % level. On average the revenue from pig production per pig unit for farms with no violations was 27310 DKK, and 23680 DKK for farms with an admonition. The one-way

ANOVA for specialized slaughter pig producers does not show any significant differences in revenue from pig production per pig unit and the most severe violation.

8.4.3. AnyViolation

It can be seen from figure 8.17 that for integrated pig producers there is no difference in revenue between farmers who violate animal welfare legislation and those who do not. The difference can be observed for specialized slaughter pig producers, where farmers who violate the animal legislation have higher revenue.

In order to investigate the statistical significance of the differences we use a two-sample t-test. The test confirms that there is no difference in average revenue between integrated pig producers that violate animal welfare legislation and integrated pig producers that do not violate any of the animal welfare regulations. The observed difference for specialized slaughter pig producers is significant at 10% significance level (t-test statistic equal to t =-1.749 with p-value = 0.096). Specialized slaughter pig producers with no violations have revenue per pig unit of 18,136 DKK on average, whereas specialized slaughter pig producers with violations have revenues of 19,160 DKK on average.

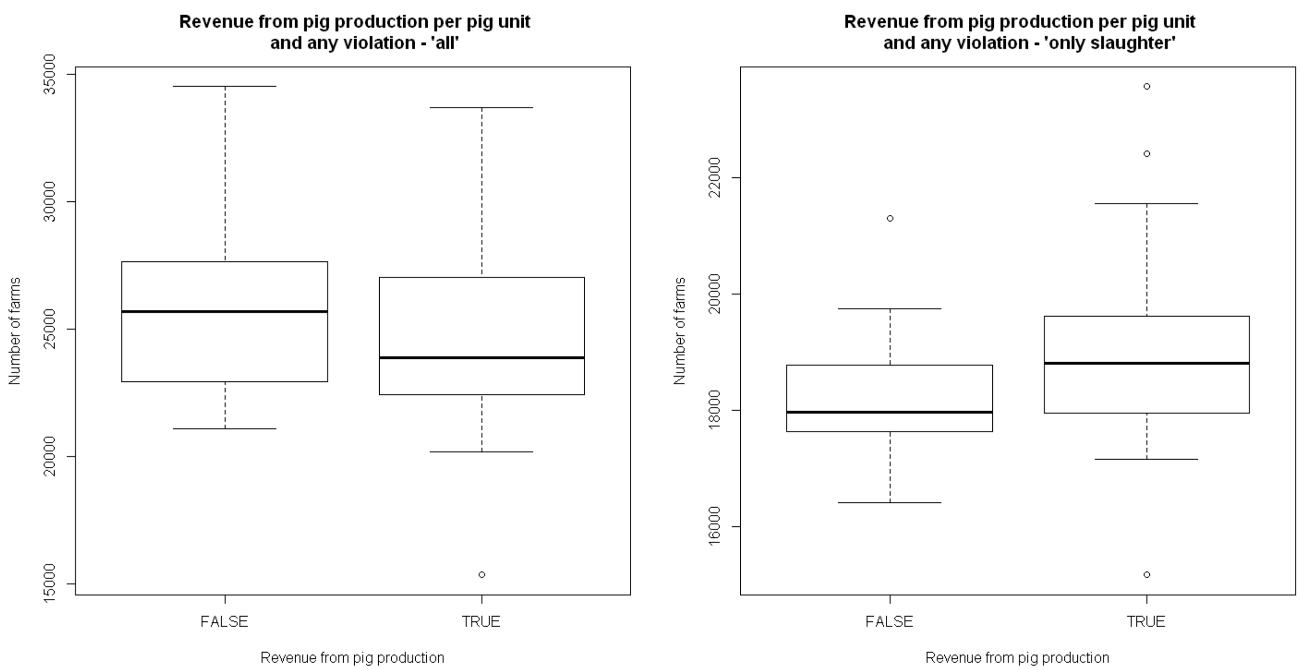

Figure 8.17. Revenue from pig production per pig unit (DKK) and AnyViolation for integrated pig producers and specialized slaughter pig producers

8.4.4. Rooting Materials

The t-test revealed statistically significant difference (t-test statistic equal to t = 3.138 with p-value = 0.004) in average revenue from pig production between farms that violate the animal welfare legislation regarding provision of rooting and playing material for integrated pig producers. Farms that do not violate these requirements have on average revenue ca. 25,858 DKK per pig unit whereas those which violate have revenue approximately 23,014 DKK on average. For specialized slaughter pig producers there is no significant difference.

8.4.5. Sick Animals

According to the performed t-test we can conclude that there is no difference in revenue from pig production per pig unit between farms with and without violations of animal welfare requirements regarding treatment of sick animals for both production types.

8.5. Feed cost per pig unit and Animal Welfare

We investigated the relationship between feed cost per pig unit and violations of animal welfare legislation, however we did not observe any significant correlations or differences. Therefore detailed results are omitted in order to save space.

8.6. Other costs per pig unit and Animal Welfare

8.6.1. Total Number of Violations

The relationship between the total number of violations and other costs of pig production per pig unit is shown in the figure 8.18. Pearson' correlation test indicates that there is no correlation for integrated pig producers and there is a positive, significant correlation for specialized slaughter pig producers at the 10% significance level (t-test statistic equal to t = 1.799 with p-value = 0.080).

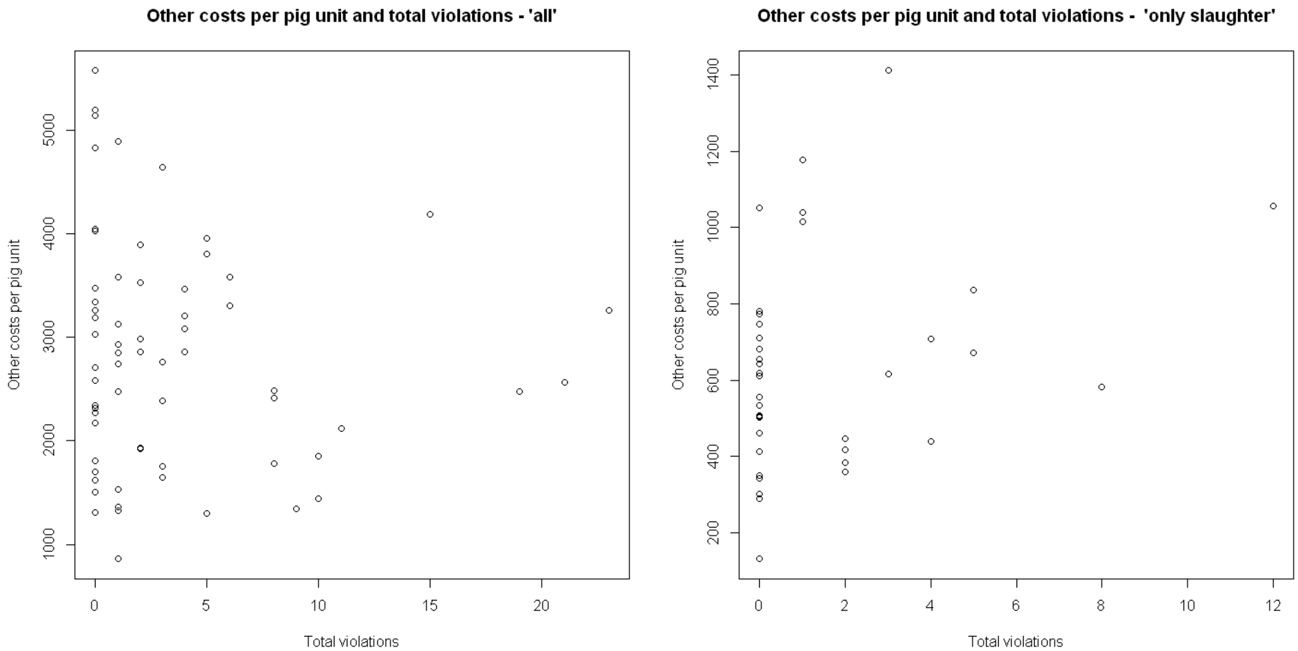

Figure 8.18. Other costs per pig unit (DKK) and total number of violations for integrated pig producers and specialized slaughter pig producers

8.6.2. Most Severe Violation

A one-way ANOVA is used to test differences in means between groups. Testing the difference for integrated pig producers and specialized slaughter pig producers is as follows:

H_0: There is no difference in the average other costs per pig unit for farms having different most severe violation for integrated pig producers (specialized slaughter pig producers).

H_1: There is a difference.

According to the results of the one-way ANOVA there are no statistical differences for both types.

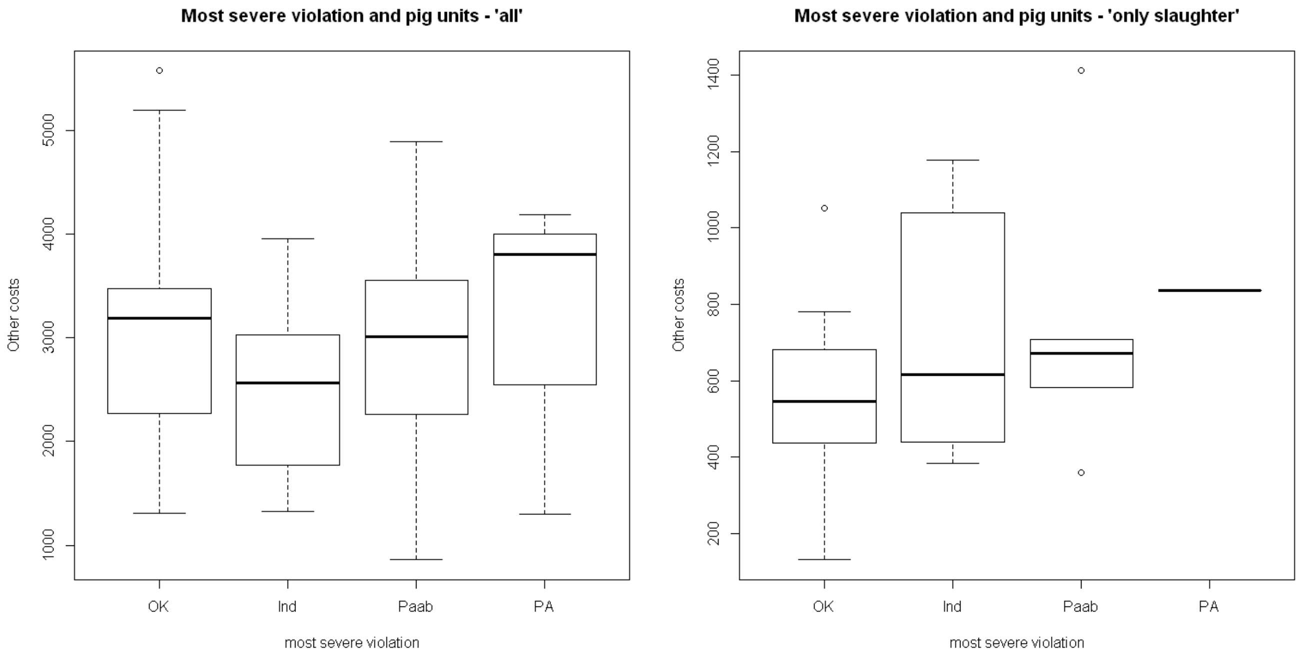

Figure 8.19. Other costs per pig unit (DKK) and most severe violation for integrated pig producers and specialized slaughter pig producers

8.6.3. AnyViolation

In order to investigate the statistical significance of the differences of the levels of the other costs between farm with and without any violations of animal welfare legislation we use a two-sample t-test. The test confirms that there is no difference in average revenue between integrated pig producers that violate animal welfare legislation and integrated pig producers that violate any of the animal welfare regulations. The observed difference for specialized slaughter pig producers is significant at the 10% significance level (t = -1.995, df = 20.439, p-value = 0.060). Farmers with no violations have other costs per pig unit of 556 DKK on average, whereas farmers with violations have costs of 744 DKK on average.

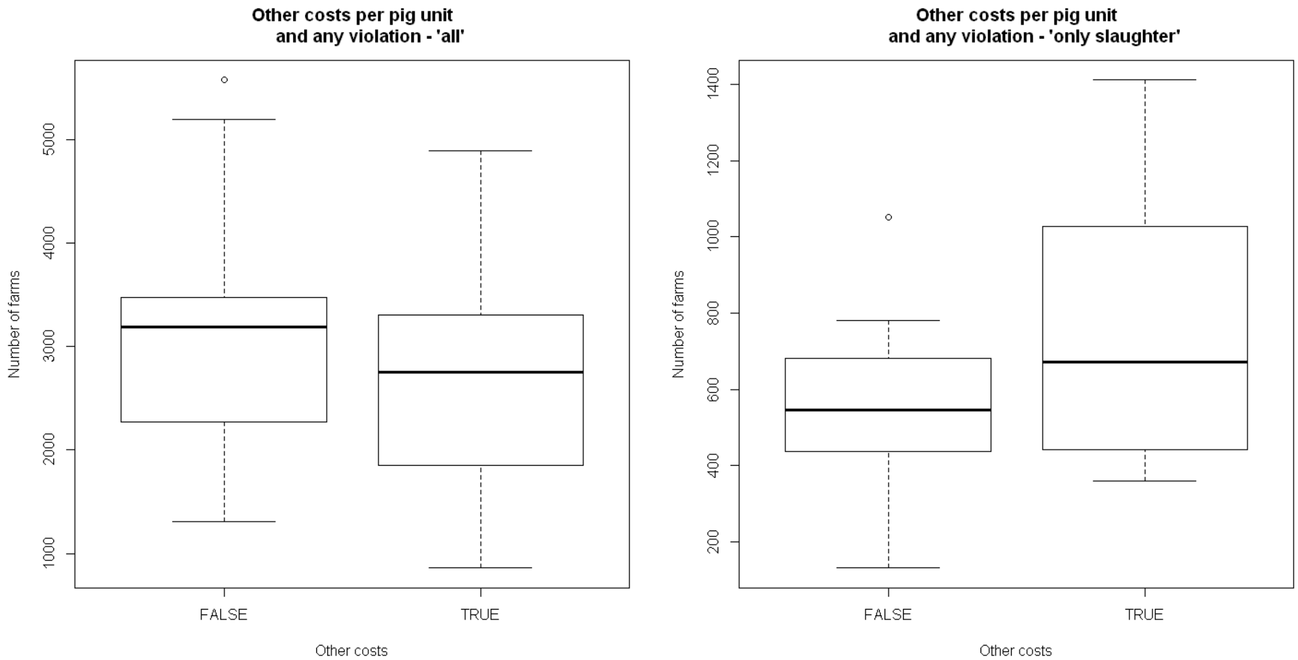

Figure 8.20. Other costs per pig unit (DKK) and AnyViolation for integrated pig producers and specialized slaughter pig producers

8.6.4. Rooting Materials and Sick Animals

There is no difference between farms which meet and do not meet the animal welfare legislation requirements regarding provision of rooting and playing materials. Using the t-test (test statistic t=-2.138 with p-value = 0.070) we found that for specialized slaughter pig producers, farms which violate animal welfare legislation regarding sick animals have higher other costs.

8.7. Age, Experience and Animal Welfare

Anneberg (2013) study the risk factors related to farmers being convicted of violating the animal welfare legislation. She finds that farmers defined as having minor production difficulties are less likely to have been convicted of neglect of their animals than any other risk group. This group of farmers is also significantly older. Age has also been shown to be correlated with the performance of the farm in other studies, e.g. Olsen and Henningsen (2011). This section studies whether there is a significant relationship between age and animal welfare. Age is used as a proxy for experience, and one could hypothesize that young farmers have worse animal welfare than older farmers as they are more inexperienced.

8.7.1. Age

It can be seen from figure 8.21 that the age of farmers with violations versus farmers without violations do not show any clear differences[12]. The age of farmers having violations is more spread out, but there does not seem to be any significant differences.

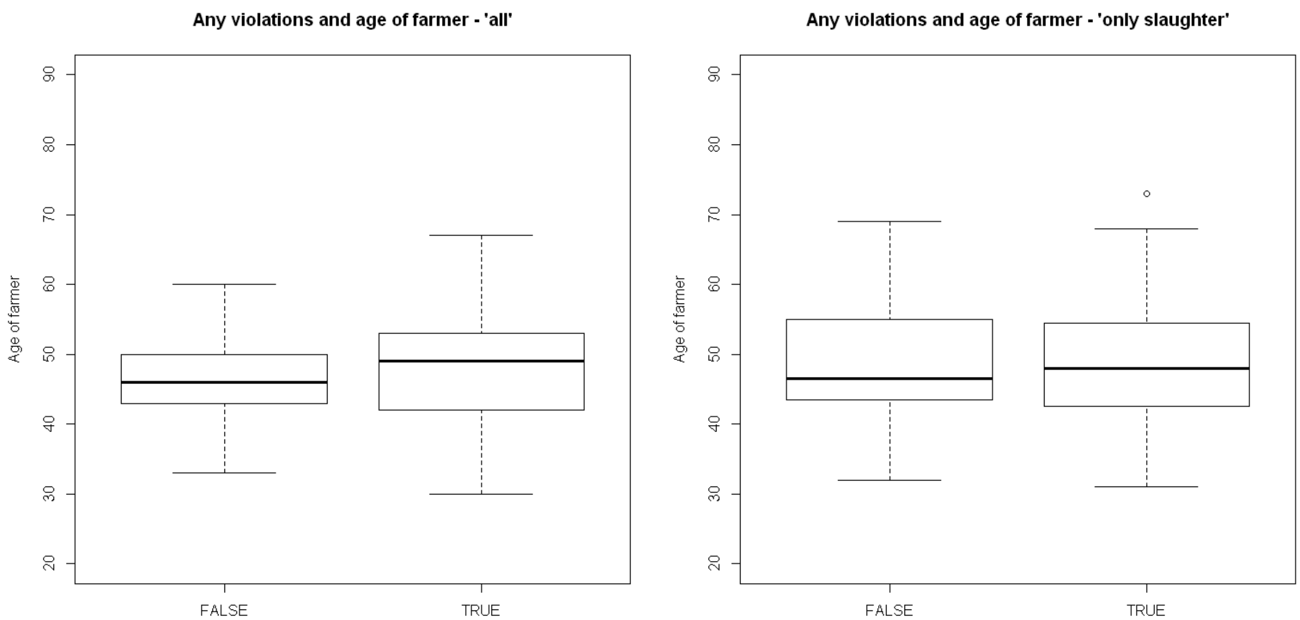

Figure 8.21. Age of the farmer and farms with and without violations for integrated pig producers and specialized slaughter pig producers

Correlation tests showed that the correlation between the total number of violations and the age of the farmer is almost zero and non-significant at the 10 % level. Neither were there any significant differences using the indicator "most severe violation."

8.7.2. Experience

Another proxy of experience is the year of establishment of the farm studied13. Once established a farmer typically do not sell his farm before he stops farming entirely. Therefore the year of establishment can be used as a proxy of the years a farmer has been managing a farm, and therefore experience in pig production. Figure 8.22 shows that there is no difference between farms with violations and farms without violations. They approximately have the same median and variation. Differences are also insignificant when using the indicators "most severe violation" and "total number of violations."

[12] When analyzing "age" 7 observations have been excluded, and therefore 129 observations are used. The exclusions were due to missing values for "age".
[13] The following analysis is based on 134 observations due to missing data on the year of establishment for one farm.

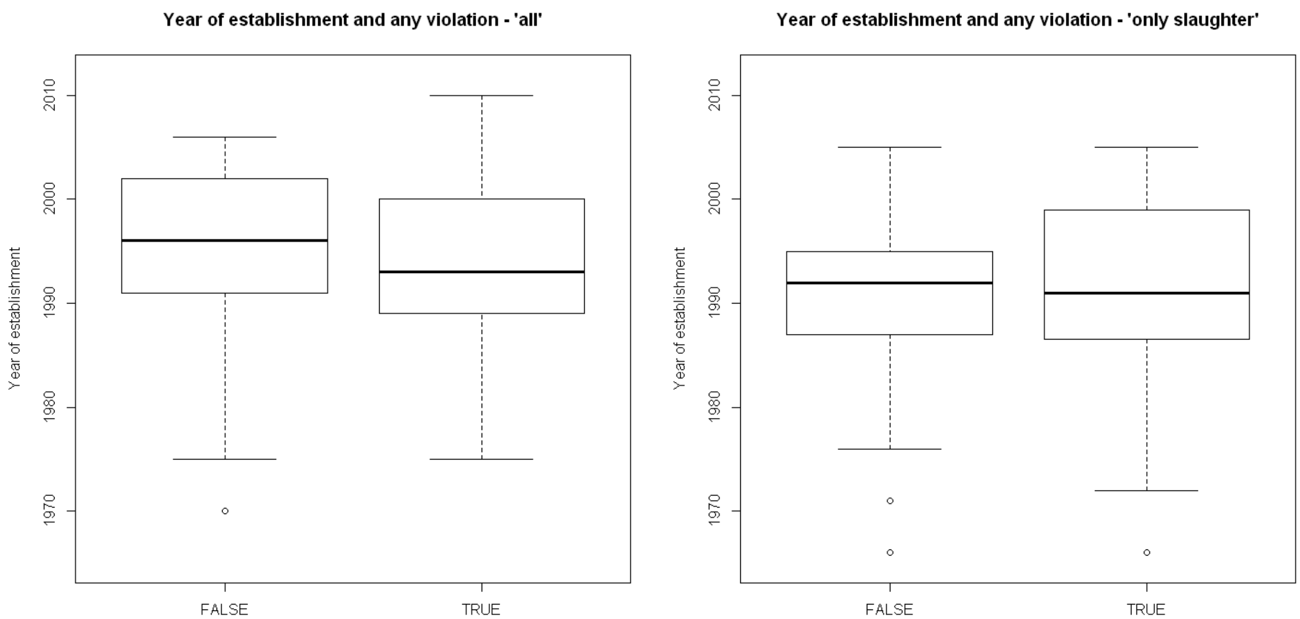

Figure 8.22. Year of establishment of the farm and farms with and without violations for integrated pig producers and specialized slaughter pig producers

8.8. Multivariate analysis of Animal Welfare and Economic outcome

The correlation analysis only allows to analyze the relationship between two factors at the time. Therefore, it ignores possible correlations between the analyzed variables and other factors. This can be solved using multivariate regression methods. In this section we present the results of regression analyses of animal welfare indicators on socio-economic variables (e.g. proxy of farm experience, size of farm and dummy variables indicating the type of production etc.) and the results of regression analyses of economic outcome variables (gross margin, veterinary costs) on animal welfare indicators and socio-economic variables.

8.8.1. Animal Welfare indicators versus socio-economic indicators

In this section we present results of the multivariate regression analyses of the relationship between animal welfare indicators and socio-economic indicators. The socio-economic indicators used in this part of the analysis consists of variables that represent the farm size, the age of the farmer, and the year of the establishment of the farm (as proxies for experience)[14]. Additionally, we use three dummy variables that indicate whether the farm has sows, piglets, and slaughter pigs[15]as well as their interactions with farm size and

[14] We found that variables representing the age of the farmer and the year of the establishment of the farm are highly correlated. The data on the age of farmer was not available for 2 farms, therefore in final analysis we use the year of the establishment of the farm as a proxy of experience.
[15] These dummy variables (and their interactions) represent the farm's type of production.

animal welfare indicators (AnyRooting and AnySick). We do not use the gross margin as explanatory variable, because we assume that animal welfare is not directly influenced by the gross margin, which is a proxy for productivity (see section 3.7). We also do not use medicine and veterinary cost as explanatory variable, because the endogeneity of this variable likely results in inconsistent estimates.

Because the indicators of animal welfare that we use in this report are not numeric variables, we cannot use basic linear regression methods (e.g. OLS) to investigate the relationship between them and the socio-economic variables. For instance the indicator "total number of violations" is not acontinuous variable but a count variable and hence, should be modeled using count data models. In such cases, usually the Poisson model is used. However due to over-dispersion of zero values in the indicator "total number of violations" we use the negative binomial model. The results of the unrestricted[16] model and the restricted model are presented in the table 8.1. The first two columns of the table contains the names of the variables and corresponding parameters. Next two columns presents results (estimated parameter, its standard error and corresponding p-value) of the unrestricted and restricted models. Last row of the table presents the value of the Akaike information criterion (AIC) which is used to select the most appropriate model. The best model is characterized by the lowest AIC value.

The only coefficient that is significantly different of zero in the restricted model is the coefficient of the dummy variable indicating whether or not the farm has sows. However, a likelihood ratio test indicates that the total effect of having slaughter pigs (i.e. including interaction effects) is also significantly different from zero.

According to our results, farms which have sows are more likely to violate the animal welfare legislation and violate more regulations than the farms that do not have sows (e.g. integrated pig producers vs. farms that only produce slaughter pigs) but this effect seem to diminish with farm size (pig units). The estimated effect of having slaughter pigs (e.g. integrated pig producers vs. piglet producers) on violations of the animal welfare legislation is much larger and it seems to depend even more on farm size (pig units), but the estimates of this effect are rather imprecise.

The indicators AnyRooting, AnySick, and AnyViolation are binary variables (e.g. either the farm has a violation or not).Therefore, we used the logit (binary choice) models for analyzing the determinants of these animal welfare indicators.

[16] The unrestricted model is the model that includes all the variables being considered as possible explanatory variables, whereas the restricted model includes only the variables selected according to the step wise model selection procedure. In this analysis we used the step-wise model selection procedure based on the minimisation of the Akaike information criterion (AIC).

Table 8.1. Results of negative binomial regression of the indicator "total number of violations"

		Unrestricted model			Restricted model		
Variable	Parameter	Estimate	S.E.	Variable	Parameter	Estimate	S.E.
Intercept	α_0	-39.680	43.370	0.360	-40.799	43.816	0.352
Size	α_1	0.161	0.173	0.353	0.163	0.175	0.351
Establishment	α_2	0.000	0.001	0.734	-	-	-
H_{Sows}	α_3	1.855	0.711	0.009	1.445	0.484	0.003
$H_{piglets}$	α_4	-0.948	0.810	0.242	-	-	-
$H_{slaughter}$	α_5	40.880	43.340	0.346	41.032	43.814	0.349
H_{Sows} * Size	α_6	-0.003	0.001	0.059	-0.002	0.001	0.111
$H_{piglets}$ * Size	α_7	0.003	0.003	0.323	-	-	-
$H_{slaughter}$ * Size	α_8	-0.162	0.173	0.348	-0.163	0.175	0.352
AIC		527.131			522.876		

The results of the logistic regression of variable AnyRooting are presented in table 8.2. In the unrestricted logit regression model of the AnyRooting indicator, t-tests and likelihood ratio tests indicate that none of the explanatory variables has a statistically significant (total) effect.

Table 8.2. Results of logistic regression of AnyRooting indicator

		Unrestricted model			Restricted model		
Variable	Parameter	Estimate	S.E.	p-value	Estimate	S.E.	p-value
Intercept	α_0	14.428	48.610	0.767	-2.021	0.528	0.000
Size	α_1	0.039	0.061	0.529	0.003	0.001	0.021
Establishment	α_2	-0.013	0.023	0.579	-	-	-
H_{Sows}	α_3	1.467	1.057	0.165	1.159	0.712	0.103
$H_{piglets}$	α_4	-0.058	1.243	0.963	-	-	-
$H_{slaughter}$	α_5	9.271	15.077	0.539	-	-	-
H_{Sows} * Size	α_6	-0.005	0.002	0.035	-0.004	0.002	0.027
$H_{piglets}$ * Size	α_7	0.000	0.004	0.971	-	-	-
$H_{slaughter}$ * Size	α_8	-0.035	0.061	0.563	-	-	-
AIC		157.856			150.635		

The restricted model is significant in variables representing the size of farm and its interaction with the dummy variable indicating whether the farm has sows or not. This means that the larger the farm, the more likely the animal welfare legislation regarding rooting and playing materials is violated. However, this relationship can only be observed for farms without sows (i.e. mainly slaughter pig farms), because the sum of the coefficient of the farm size and the coefficient of the interaction effect between farm size and the dummy variable for sows is close to zero. The effect of having sows on the likelihood of violating animal welfare legislation regarding rooting and playing materials depends on the size of the farm.

The results of the logistic regression of variable AnySick are presented in table 8.3. Both the restricted model and the unrestricted model of the AnySick indicator, t-tests and likelihood ratio tests indicate that none of the explanatory variables have a statistically significant (total) effect. Therefore, we cannot draw any conclusions regarding the relationship between the explanatory variables and the dependent variable.

Table 8.3. Results of logistic regression of AnySick indicator

Variable	Parameter	Unrestricted model			Restricted model		
		Estimate	S.E.	p-value	Estimate	S.E.	p-value
Intercept	α_0	-128.400	112.500	0.254	-70.716	50.211	0.159
Size	α_1	0.250	0.404	0.536	-	-	-
Establishment	α_2	0.032	0.026	0.223	0.035	0.025	0.167
H_{Sows}	α_3	-0.981	0.992	0.322	-	-	-
$H_{piglets}$	α_4	1.985	1.322	0.133	-	-	-
$H_{slaughter}$	α_5	62.190	102.100	0.542	-	-	-
H_{Sows} * Size	α_6	0.002	0.002	0.383	-	-	-
$H_{piglets}$ * Size	α_7	-0.005	0.005	0.277	-	-	-
$H_{slaughter}$ * Size	α_8	-0.246	0.404	0.543	-	-	-
AIC		149.554			141.924		

The results of the logistic regression of the variable AnyViolation are presented in table 8.4. The restricted model is only significant in the parameter of the dummy variable that indicates whether sows are kept at the farm or not. This means that farms that have sows are more likely to violate animal welfare legislation than the farms which do not have sows (e.g. integrated pig farms vs. slaughter pig producers). This also supports our findings regarding the violations of animal welfare legislation regarding provision of rooting and playing materials presented above.

Table 8.4. Results of logistic regression of AnyViolation indicator

Variable	Parameter	Unrestricted model			Restricted model		
		Estimate	S.E.	p-value	Estimate	S.E.	p-value
Intercept	α_0	-11.960	45.362	0.792	-16.164	21.282	0.448
Size	α_1	0.059	0.086	0.491	0.060	0.085	0.481
Establishment	α_2	-0.002	0.020	0.915			
H_{Sows}	α_3	1.330	0.910	0.144	0.671	0.373	0.072
$H_{piglets}$	α_4	-0.582	1.027	0.571			
$H_{slaughter}$	α_5	16.083	21.404	0.452	15.763	21.282	0.459
H_{Sows} * Size	α_6	-0.002	0.002	0.235			
$H_{piglets}$ * Size	α_7	0.004	0.004	0.347			
$H_{slaughter}$ * Size	α_8	-0.061	0.086	0.481	-0.060	0.085	0.486
AIC		192.01			185.55		

We used the count data and binary choice models in order to investigate the relationship between animal welfare indicators and socio-economic variables. The main conclusion is that the violation of animal welfare legislation generally does not depend on socio-economic factors such as the farm size or the farmer's experience.

8.8.2. Economic outcome versus Animal Welfare indicators

In this section we analyze the relationship between economic outcome and animal welfare, where we treat the economic indicators (gross margin per pig unit and veterinary and medicine costs per pig unit) as dependent variables.

The explanatory variables used in both models are animal welfare indicators (total number of violations, AnyRooting, AnySick) and other farm characteristics (3 dummy variables indicating whether farm has sows, piglets and slaughter pigs, respectively, a variable denoting size of farm (measured in pig units), and the year of establishment of the farm as a proxy of farmer's experience).

The results of the linear regression of gross margin are presented in table 8.5. On the left-hand side of the table, the results of the general (unrestricted) regression model are presented. Most estimated parameters of the unrestricted model are insignificant at the 10% significance level. However all estimated parameters together are significant what is indicated by the F statistic. On the right-hand side of the table, the results of the restricted model which has been selected according to the lowest value of the AIC criterion in the step-wise model selection procedure. Based on the restricted model, we found that the only significant animal welfare indicator is the one which indicates whether the animal welfare legislation regarding the sick animals is violated or not. According to the estimated model, farms which violate these animal welfare requirements have on average a lower gross margin. The remaining indicators of animal welfare are insignificant. Based on the estimated parameter of the dummy variable that indicates whether the farm produces piglets, we can conclude that farms which produce piglets have on average higher gross margin per animal unit. Although the variable that denotes the size of the farm is statistically insignificant, the interaction terms of this variable with dummy variables representing different types of production are statistically significant. This means that larger farms have on average higher gross margin per pig unit.

Table 8.5. Results of linear regression of gross margin

Variable	Unrestricted model				Restricted model		
	Parameter	Estimate	S.E.	p-value	Estimate	S.E.	p-value
Intercept	α_0	-31552.204	66815.613	0.638	-177.660	3997.598	0.965
Total violations	α_1	-31.116	85.455	0.716			
AnyRooting	α_2	6475.114	4108.560	0.118	1205.098	1064.871	0.260
AnySick	α_3	-616.327	4328.612	0.887	-1795.573	711.869	0.013
Establishment	α_4	15.450	33.406	0.645			
Size	α_5	27.042	21.023	0.201	28.589	18.417	0.123
H_{Sows}	α_6	636.465	1624.122	0.696	697.539	1388.550	0.616
$H_{piglets}$	α_{10}	3633.259	1755.396	0.041	2542.811	1036.303	0.016
$H_{slaughter}$	α_{11}	4912.150	4133.948	0.237	5055.129	3947.335	0.203
H_{Sows} * AnyRooting	α_7	-2569.414	2084.193	0.220	-3510.939	1397.650	0.013
$H_{piglets}$ * AnyRooting	α_8	-1736.737	2319.990	0.456			
$H_{slaughter}$ *	α_9	-4692.519	3856.868	0.226			
H_{Sows} * AnySick	α_{12}	-78.013	1937.705	0.968			
$H_{piglets}$ * AnySick	α_{13}	-1470.822	2316.777	0.526			
$H_{slaughter}$ * AnySick	α_{14}	77.776	3977.188	0.984			
H_{Sows} * Size	α_{15}	6.004	3.330	0.074	6.356	2.829	0.026
$H_{piglets}$ * Size	α_{16}	-2.888	6.328	0.649			
$H_{slaughter}$ * Size	α_{17}	-26.614	20.248	0.191	-31.173	18.281	0.091
R2 (Adjusted R2)		0.378 (0.286)			0.353 (0.306)		
F-statistics		4.138 (17, 116), p-value: 0.000			7.519 (9, 124), p-value: 0.000		
AIC		2572.688			2561.844		

Next we investigated the relationship between medicine and veterinary costs and animal welfare indicators and other farm characteristics. The estimation procedure and model selection was the same as in case of the regression model of the gross margin. The results are presented in table 8.6.

Based on the restricted linear regression model of medicine and veterinary costs, we found that these cost generally do not depend on the animal welfare indicators. There is one small exception from this result: farms which do not have slaughter pigs and violate animal welfare regulations have on average higher costs than corresponding farms that do not violate animal welfare regulations, but there are only few farms of this type (7.6%) in the sample.

Table 8.6. Results of the linear regression of medicine and veterinary costs

Variable	Parameter	Unrestricted model Estimate	Unrestricted model S.E.	Unrestricted model p-value	Restricted model Estimate	Restricted model S.E.	Restricted model p-value
Intercept	α_0	-6392.000	7680.000	0.407	-337.211	444.437	0.449
Total violations	α_1	-7.120	9.644	0.462			
AnyRooting	α_2	1142.000	463.200	0.015	903.499	402.714	0.027
AnySick	α_3	358.900	488.000	0.464	117.932	165.176	0.477
Establishment	α_4	3.043	3.837	0.429			
Size	α_5	4.421	2.372	0.065	4.93	2.100	0.021
H_{Sows}	α_6	561.000	184.300	0.003	515.447	93.122	0.000
$H_{piglets}$	α_{10}	275.600	201.000	0.173	302.075	111.941	0.008
$H_{slaughter}$	α_{11}	592.300	466.000	0.206	577.649	442.375	0.194
H_{Sows} * AnyRooting	α_7	-153.700	238.400	0.520			
$H_{piglets}$ * AnyRooting	α_8	-14.810	264.800	0.956			
$H_{slaughter}$ * AnyRooting	α_9	-1150.000	434.800	0.009	-1036.895	410.295	0.013
H_{Sows} * AnySick	α_{12}	56.940	221.200	0.797			
$H_{piglets}$ * AnySick	α_{13}	-272.000	263.400	0.304	-265.568	186.955	0.158
$H_{slaughter}$ * AnySick	α_{14}	-275.800	448.400	0.540			
H_{Sows} * Size	α_{15}	0.003	0.386	0.993			
$H_{piglets}$ * Size	α_{16}	0.104	0.728	0.886			
$H_{slaughter}$ * Size	α_{17}	-4.720	2.283	0.041	-5.073	2.105	0.017
R2 (Adjusted R2)		0.602 (0.547)			0.596 (0.566)		
F-statistics		10.870 (16, 115), p-value: 0.000			19.960 (9, 122), p-value: 0.000		
AIC		1957.027			1945.147		

We can conclude that the level of medicine and veterinary costs depends on the type of production rather than on the compliance with animal welfare legislation. For instance, farms which have sows and/or piglets have on average higher medicine and veterinary cost.

8.9. Estimation of the Stochastic Output Distance Function

The stochastic output distance function estimated as an efficiency effect frontier makes it possible to study multiple inputs and multiple outputs of agricultural production in relation with animal welfare. In this specification, the stochastic frontier model consists of two parts: the stochastic frontier equation and the inefficiency equation. Contrary to the descriptive economic analysis, the stochastic output distance function analyses the overall performance of pig producers and the relationship to animal welfare. The stochastic output distance function is estimated with 120 observations.[17]

[17] Observations have mainly been excluded due to missing values of explanatory variables (11 farms with missing data on land input and 3 with missing data on labor input) and two outliers with implausible values of input variables were also excluded.

8.9.1. Model variables

The stochastic frontier part of the efficiency effects stochastic output distance function includes 2 outputs and 6 inputs. Animal output is measured as the net value of animal production[18]. The second output variable consists of crop outputs and any revenue from supply of services. Intermediate pig inputs include medicine and veterinary costs, and other miscellaneous pig inputs. Other intermediate inputs include crop inputs such as fertilizers, seed, pesticides, miscellaneous crop inputs and inputs not readily allocated to either crop or pig production. Capital is measured as the consumption of capital during the year. Additionally, a set of three dummy variables indicating whether farm has sows, piglets and slaughter pigs is included in the frontier part of the model to capture possible differences in technology between the different production types of farms.

The inefficiency equation includes a set of variables indicating animal welfare (e.g. total number of violations, AnySick and AnyRooting), and the variable size (measured in number of pig units) and establishment (the year of establishing the farm as a proxy of farmer's experience). Additionally, the dummy variables indicating the type of production and their interactions with two indicators of animal welfare (AnySick and AnyRooting) are also included in the inefficiency part of the model.

Summary of descriptive statistics of variables used in the estimation of the stochastic output distance functions is presented in the table 8.7.

Table 8.7. Descriptive statistics of variables used in estimation of stochastic output distance function

Variable name	Variable	Unit	Mean	Std. Dev.
Animal output	Y_1	Thousand DKK	6,777	4,960
Other outputs	Y_2	Thousand DKK	1,911	1,368
Feed	X_1	Thousand DKK	4,212	2,886
Intermediate pig input	X_2	Thousand DKK	415	444
Other intermediate inputs	X_3	Thousand DKK	1,337	819
Land	X_4	Hectares	200	129
Labor	X_5	Hours	4,903	3,884
Capital	X_6	Thousand DKK	4,474	3,541
"Has sows"	H_{Sows}	Dummy variable	56%*	
"Has piglets"	$H_{piglets}$	Dummy variable	70%*	
"Has slaughter"	$H_{slaughter}$	Dummy variable	93%*	
Total violations	Total violations	Number of violations	2.55	4.30
Rooting material - Violating regulations	AnyRooting	Dummy variable	23%*	
Sick animals - Violating regulations	AnySick	Dummy variable	22%*	
Number of pigs	Pig units	Pig units	287	209

**Frequency of 1*

[18]Net production of animals is the value of the livestock at the end of the year minus the value of the livestock at the beginning of the year plus the value of all sold animals and animal products minus the value of all purchased animals.

8.9.2. Results of the Estimation

The results of the conducted stochastic frontier analysis are presented in table 8.8. The estimation is performed by the add-on package "frontier" (Coelli and Henningsen 2012).The upper part of the table presents the results of the output distance function model of the SFA. The bottom part of the table provides the results of the inefficiency model of the SFA. The first two columns consist of the variable names and corresponding parameters. Next two columns present the estimation results of the unrestricted and restricted models. The difference between these two models is in the set of the variables that are used in the inefficiency model. The unrestricted model includes all variables that are described in the previous subsection. The likelihood ratio test is used to test the restricted model against the unrestricted model. Using a likelihood ratio test, we found that the model, in which inefficiency only depends on the total number of violations, AnyRooting, AnySick, and the farm size fits the data not significantly worse than the unrestricted model[19].

We also tested the stochastic frontier model against its OLS counterpart using a likelihood ratio test. This test allows to check whether the inefficiency term is statistically significant. The likelihood ratio test statistics is equal to 48.340 with p-value smaller than 0.001 for the restricted model, therefore we conclude that the OLS model (without inefficiency) is clearly rejected. The gamma parameter (γ) indicates whether deviations from the frontier are due to noise or due to technical inefficiency. The estimated value of the gamma parameter is equal to 0.450. This means that both the statistical noise and the technical inefficiency are important in explaining deviations from the frontier. The rather large share of the noise component in the composite error term supports the use of stochastic frontier analysis instead of the deterministic method.

The frontier part of the estimated model can be used to investigate the production (frontier) technology of the analyzed farms. However, in this analysis the main focus is on the relationship between technical efficiency and animal welfare indicators, therefore we use the frontier estimates to check the general economic consistency of the model (e.g. we check the monotonicity conditions). The distance elasticities of the inputs in the stochastic output distance function (given by the parameters β) can be interpreted as the relative effect on the aggregate output given a 1% increase in the particular input quantity. For instance, increasing (decreasing) the feed input by 1 % would increase (decrease) the aggregate output by around 0.53%. We found that all input elasticities are negative (although the estimated parameters of variable other inputs and labor are not significantly different from zero), which means that the monotonicity conditions are globally fulfilled. This indicates that signs of the distance elasticities of the inputs are consistent with microeconomic theory, as they

[19] We used also the Likelihood ratio test to test the joint significance of all animal welfare indicators. Based on this test, we found that all animal welfare indicators are jointly significant.

imply that increasing any of the input quantities can never decrease the output quantity. The elasticity of scale obtained from the output distance function is equal to the negative sum of the distance elasticities of the inputs. The calculated elasticity of scale is around 0.92 what indicates that the analyzed farms produce under decreasing returns to scale. The elasticity of scale of Danish pig producers has been estimated in other studies. Rasmussen (2010) found that the elasticity of scale of Danish pig farms declined from 1.25 in 1986 to 1.13 in 2006. The average elasticity of scale in the period was 1.19. Olsen and Henningsen (2011) found the elasticity of scale to be 1.06 on average over during the years 1996-2008. Both studies find Danish pig producers to operate under increasing returns to scale. The differing results could be due to the estimation method used or due to the structure of the data – in this report the cross-sectional data was used whereas Rasmussen (2010) and Olsen and Henningsen (2011) used panel data sets.

A positive parameter estimate of a z-variable indicates a positive relationship between the z-variable and the inefficiency term *u*. The estimated parameter of the total number of violations (δ_1) in the inefficiency model is positive and statistically significant. This means that having violations of animal welfare increases the technical inefficiency (decrease technical efficiency). Similar findings regarding the relationship between the animal welfare indicator and technical efficiency are found for variable AnySick, as its estimated parameter (δ_1) is also positive and statistically significant (at the 10% significance level). This means that farms which violate regulations regarding sick animals are on average less efficient.

The estimated parameter of the remaining animal welfare indicator, AnyRooting, is negative, though it is non-significant. The negative sign of the estimated parameter of AnyRooting would indicate that violating animal welfare regulations regarding rooting and playing materials increases technical efficiency. This would not be surprising, since provision of rooting and playing materials for animals might create additional costs for the farmer (cost of material, e.g. straw, cost of additional labor to provide fresh rooting material and remove the used one, etc.).

However, based on the presented estimate we can not draw such conclusion. To further investigate the relationship between welfare legislation regarding rooting materials and technical efficiency, a larger sample or preferably panel data should be used in the analysis.

Table 8.2. Estimation results the stochastic output distance function

Inefficiency effect stochastic frontier output distance function							
		Unrestricted model			Restricted model		
Variable	Parameter	Estimate	S.E.	p-value	Estimate	S.E.	p-value
Stochastic frontier output distance function:							
Intercept	α_0	7.834	75.656	0.918	-3.297	0.629	0.000
Animal output	$\alpha_1 = 1-\alpha_2$	0.750	-	-	0.793	-	-
Other outputs	α_2	0.250	0.031	0.000	0.207	0.032	0.000
Feed	β_1	-0.599	0.047	0.000	-0.534	0.053	0.000
Intermediate pig input	β_2	-0.076	0.022	0.000	-0.114	0.026	0.000
Other intermediate	β_3	-0.124	0.041	0.002	-0.069	0.042	0.102
Land	β_4	-0.109	0.032	0.001	-0.126	0.035	0.000
Labor	β_5	-0.022	0.021	0.287	-0.032	0.025	0.204
Capital	β_6	-0.079	0.020	0.000	-0.045	0.022	0.037
H_{Sows}	ρ	-9.565	75.669	0.899	0.048	0.040	0.235
$H_{piglets}$	ρ	0.024	0.027	0.366	-0.004	0.031	0.898
$H_{slaughter}$	ρ	-9.466	75.664	0.900	-0.048	0.040	0.229
Inefficiency equation:							
Intercept	δ_0	-9.001	75.920	0.906	0.375	0.081	0.000
Total violations	δ_1	0.002	0.003	0.479	0.008	0.004	0.026
AnyRooting	δ_2	-68.059	542.730	0.900	-0.052	0.045	0.249
AnySick	δ_3	0.648	0.228	0.004	0.094	0.054	0.084
Size	δ_4	-0.002	0.002	0.160	-0.002	0.001	0.000
Establishment	δ_5	0.000	0.001	0.941	-	-	-
H_{Sows}	δ_6	9.630	75.598	0.899	-	-	-
$H_{piglets}$	δ_7	-0.281	0.232	0.226	-	-	-
$H_{slaughter}$	δ_8	9.442	75.669	0.901	-	-	-
H_{Sows} * AnyRooting	δ_9	46.658	379.220	0.902	-	-	-
$H_{piglets}$ * AnyRooting	δ_{10}	-21.230	174.900	0.903	-	-	-
$H_{slaughter}$ * AnyRooting	δ_{11}	42.650	338.400	0.900	-	-	-
H_{Sows} * AnySick	δ_{12}	0.195	1.093	0.858	-	-	-
$H_{piglets}$ * AnySick	δ_{13}	-0.308	1.131	0.785	-	-	-
$H_{slaughter}$ * AnySick	δ_{14}	-0.488	0.131	0.000	-	-	-
H_{Sows} * Size	δ_{15}	0.001	0.002	0.503	-	-	-
$H_{piglets}$ * Size	δ_{16}	0.001	0.002	0.611	-	-	-
$H_{slaughter}$ * Size	δ_{17}	0.000	0.001	0.950			
	σ^2	0.010	0.002	0.000	0.011	0.003	0.001
	γ	0.562	0.126	0.000	0.450	0.246	0.068
log-likelihood value		126.926			117.945		
mean efficiency		0.492			0.918		

The levels of the estimated parameter values in the inefficiency equation have no direct interpretation, while the marginal effects of the z-variables have a straight-forward interpretation. In practice, this is done by the estimation software, but the formula for this calculation is derived in Olsen and Henningsen (2011).

The marginal effects of the explanatory variables of the inefficiency equation on the efficiency estimates are presented in the histograms in figures 8.23. - 8.26.

Figure 8.23 presents a histogram of the marginal effects of the total number of violations on the technical efficiency. Farms with one additional violation of the animal welfare legislation (everything else equal) have on average a 0.2 percentage points lower technical efficiency.

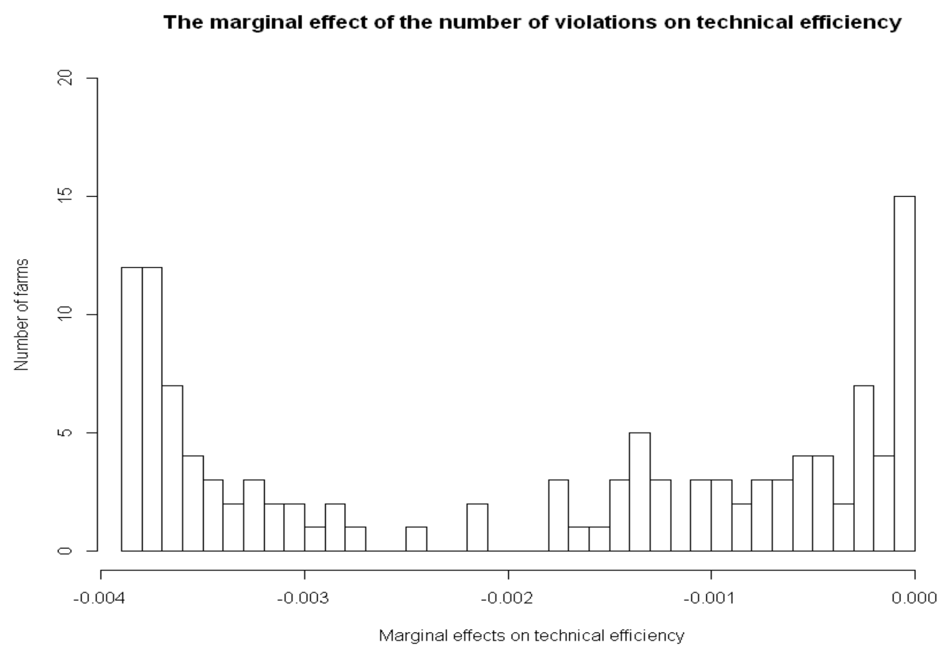

Figure 8.23. Marginal effect of the total number of violations on technical efficiency

The sign of the estimated parameter of the variable Size (measured in pig units) is negative. This means that having more pigs increases the technical efficiency. On average, farms with one additional pig unit (everything else equal) have a 0.04 percentage points higher technical efficiency (see figure 8.24). This means that larger farms are more efficient.

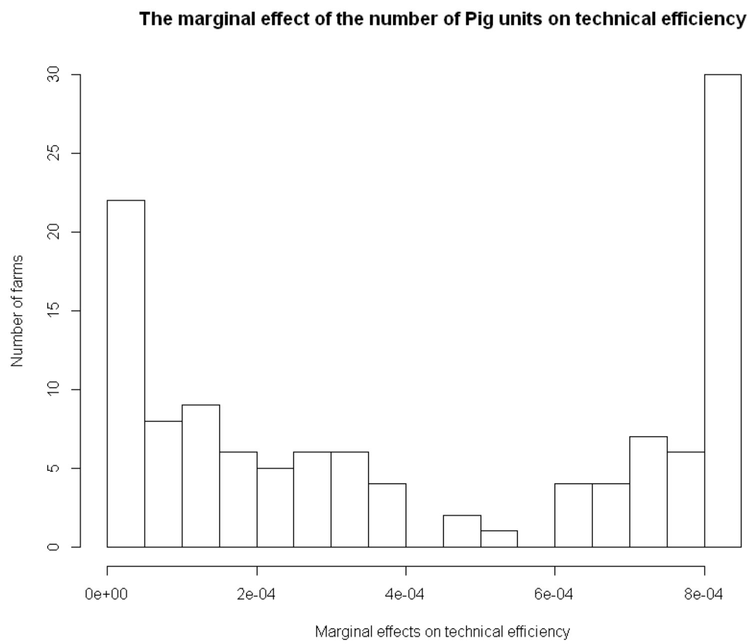

Figure 8.24. Marginal effect of the variable pig units on technical efficiency

The marginal effects of the variable AnyRooting on technical efficiency are presented in figure 8.25. Farmers who violate the regulations with regards to sick animals are on average 1.3 % less efficient than farmers that do not violate these requirements.

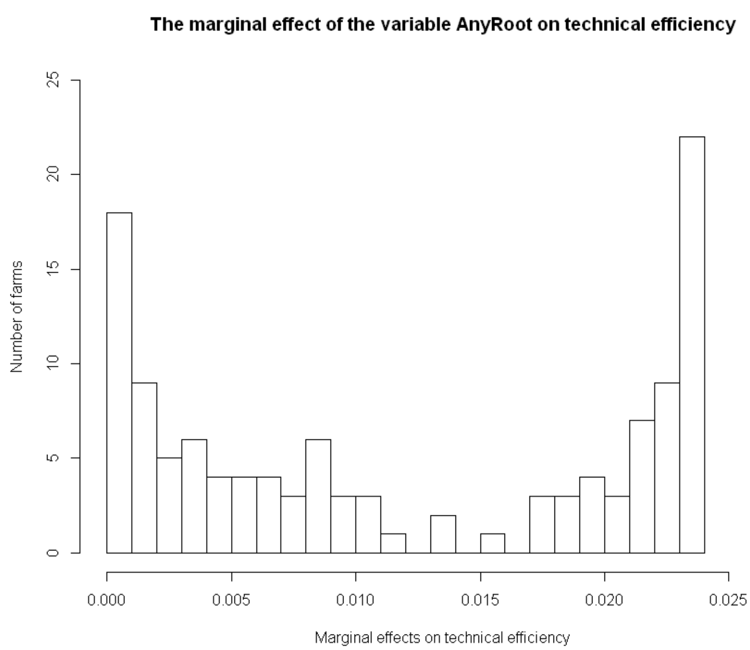

Figure 8.25. Marginal effect of the variable AnyRooting on technical efficiency

The distribution of calculated marginal effects of the AnySick variable on technical efficiency is shown in figure 8.26. Farmers who violate the regulations with regard to sick animals are on average 2.2 % less efficient than farmers that do not violate these requirements.

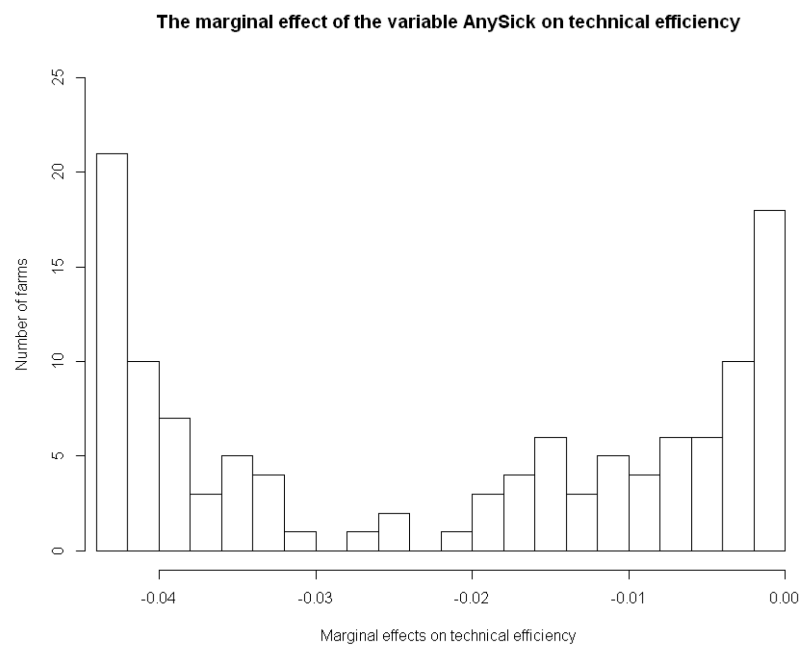

Figure 8.26. Marginal effect of the variable AnySick on technical efficiency

9. Discussion

In this section we discuss the empirical results obtained from the descriptive analysis, multivariate regression analyses and the results from the estimation of the stochastic output distance function. Moreover, we discuss the methods that we used to answer the research questions:

- Is there a relationship between the number of pigs produced by a farmer and pig welfare?
- Is there a relationship between gross margin per pig unit and pig welfare?
- Is there a relationship between medicine and veterinary cost per pig unit and pig welfare?
- Is there a relationship between the age or experience of the farmer and pig welfare?
- Is there a relationship between the technical efficiency of a farm and pig welfare?

We used the above mentioned research questions to address the main research objective which is defined as follows:

- Is there a relationship between animal welfare and economic results at the farm level?

9.1. Pig units

The structural adjustment process in pig farming has caused farms to become increasingly larger and more specialized in order to increase profit margins and to become more competitive in the global market. Winter *et al.* (1998) argue that the structural adjustment process has caused animal welfare to decrease, e.g. due to farms becoming larger. Our descriptive analysis showed that there is no clear relationship between the farm size (number of pig units at the farm)and violations of the animal welfare regulations, i.e. larger pig producers in general neither have more nor more severe violations than smaller pig producers. These results were observed both for integrated pig producers and for specialized slaughter pig producers. The multivariate analysisgenerally confirmed the descriptive analysis. It revealed a positive relationship between farm size and violations of the animal welfare legislation regarding the provision of rooting and playing materials for farms that do not have sows (mainlyspecialisedslaughter pig producers) but no relationships were found for other farm types and for other indicators of animal welfare. The main conclusion from the descriptive and the multivariate analyses is that violations of animal welfare legislation do not depend on the farm size except that large specialised slaughter pig producers have slight tendency to more often violate the regulations regarding the provision of rooting and playing materials.

In Lassen *et al.* (2012), an interviewed farmer states that given the nature of the inspection, it can be difficult to avoid having a violation when managing several thousand pigs at a farm. If this is true, our results would indicate that large farmers would be even better in following the animal welfare legislation than smaller farmers, because larger farmers generally have the same number of violations, although the regulations apply to a larger number pigs.

9.2. Gross Margin per Pig Unit

The results from our descriptive analysis indicate a positive relationship between animal welfare and gross margin per pig unit for integrated pig producers. For this type of pig producers, there is a negative correlation between the total number of violations and the gross margin per pig unit (statistically significant at the 10% significance level). This tendency is also present when comparing farms with and without violations, and also for farms violating regulations on rooting and playing materials or sick animals, i.e. farms with no violations have larger gross margins in all cases(statistically significant at the 10% significance level). For specialized slaughter pig producers, there seems to be a slightly negative relationship between animal welfare and gross margin per pig unit, i.e. farms with no violations have lower gross margins but this relationship is statistically insignificant. If we take other factors into accounting the multivariate analysis, we only find a significant relationship between the gross margin and violations of the animal welfare regulations regarding the treatment of sick animals, farms that violate these regulations have on average lower gross margins (everything else equal).

According to our theoretical considerations described in section 3.6, animal welfare could be either positively or negatively related to the gross margin (as a proxy for productivity). Our results indicate that the positive correlation (due general management qualities) at least outweighs the negative effect (due to higher costs of following the animal welfare regulations) for integrated pig producers, while for specialized slaughter pig producers the positive correlation (due general management qualities) almost outweighs the negative effect (due to higher costs of following the animal welfare regulations).

9.3. Medicine and Veterinary Costs per Pig Unit

We argued that although the costs of medicine and veterinary services are related to animals' health, it is difficult to assesswhether high medicine and veterinary costs indicate good or poor animal welfare. Our descriptive analysis indicates that there is a clear relationship between the animal welfare indicators and medicine and veterinary costs per pig unit and that the direction of this relationship depends on the type of production. In contrast, our multivariate analysis does not find a notable relationship between the animal welfare indicators and medicine and veterinary costs per pig unit. These seemingly contradictory results could mean that the correlation between the animal welfare indicators and medicine and veterinary costs per pig unit that we found in the descriptive analysis does not result from a direct relationship but from an indirect relationship through other variables that have an effect on both animal welfare indicators and medicine and veterinary costs per pig unit. The analysis of the complex relationship between animal welfare indicators, medicine and veterinary costs per pig unit, and other variables is an interesting field for future research.

9.4. Age and Experience

The Scientific Veterinary Committee (1997) argues that the quality of stockmanship has a large effect on the welfare of pigs. The results of Anneberg (2013) showed that older farmers were less likely to have been convicted of neglect. According to the results of our descriptive and multivariate analyses, the age of the farmer and the year of establishment of the farm (used as a proxy for the farmer's experience) do not show any correlation with the animal welfare indicators. This means that the manager's ability to comply with the animal welfare legislation is not correlated with the farmers' age or experience in pig production.

The reason for the difference between our findings and results of Anneberg (2013) might be that she studied farmers with regards to the likelihood of being convicted of animal welfare neglect, whereas in our analysis we studied violations in general.

It is worth to add that the use of another variable indicating farmer's management abilities, such as years of formal education might have yielded other results. Years of education is a proxy of the farmer's willingness to learn and get educated, and improve the management of a farm. However, data on the level of the formal education was not available in our data.

9.5. Technical Efficiencies

Additionally to the descriptive analysis and multivariate regression analysis we used also stochastic frontier analysis to investigate the relationship between the animal welfare indicators and the technical efficiency of pig producers. We found that violations of the animal welfare legislation are in general negatively correlated with the technical efficiency of pig producers. This means that farms with bad management of animal welfare are on average less efficient.

These results are similar to the results of the study of Barnes et al. (2011) who investigated the relationship between lameness and technical efficiency in dairy herds. Lameness as an indicator of animal welfare has an advantage over the animal welfare indicators that we used in this analysis, because it is an animal-based indicator. They found that herds with low prevalence of lameness had higher technical efficiencies, and therefore also show that there is positive correlation between good welfare management and technical efficiency. On the other hand, Lawson *et al.* (2004a) showed that dairy farms with more treatments of lameness, ketosis, and digestive disorders were more technically efficient. The opposite was true for farms reporting more treatments of milk fever, which had lower technical efficiencies.

9.6. Methods

The descriptive analysis of the economic variables and welfare indicators is a simple approach to analyzing the relationship between animal welfare and economics. This is both an advantage and a drawback. The advantage of the approach is that relationships are easily visualized and it is straightforward to check obvious correlations and differences. The drawback is that it is not possible to make any conclusions on causality, and it is not possible to account for possible correlations with other factors. Therefore we used multivariate regression analysis to get a more thorough investigation of correlations between animal welfare, socio-economic indicators and economic outcome.

The stochastic output distance function makes it possible to analyze technical efficiency and its relationship to animal welfare. This approach accounts for more outputs and more inputs so that the estimated efficiencies are better measures of productivity than gross margins that disregard labour and capital inputs. We presented the results of a Cobb-Douglas output distance function, although researchers usually prefer to use more flexible functional forms such as the translog function. However, our data set did not include a sufficient number of observations for estimating a translog output distance function so that the estimates were too imprecise due to insufficient degrees of freedom.

9.7. Data

There exist only few empirical studies that analyse the relationship between animal welfare and economic outcome at the farm level. One possible reason for this is that animal welfare is a multidimensional concept, and it is difficult to get reliable and quantifiable data and thus indicators covering all aspects of animal welfare. Moreover, data and indicators need to be available for a large number of farms in order to conduct a meaningful quantitative analysis.

In this analysis, we use data from the Danish animal welfare inspection to construct indicators of animal welfare. It should be noted that the use of welfare inspection data is not comparable to an overall welfare assessment. A welfare inspection inspects the legislative requirements, whereas a welfare assessment assesses the true level of animals' welfare. Though, the animal welfare inspection that is used in our analysis is a good proxy for the farmer's management of animal welfare with regards to certain issues. The aggregation of the animal welfare data could result in biased animal welfare indicators. These potential biases have been investigated. Conducted statistical tests showed that this aggregation does not induce a significant bias. The classification according to production type of farms ensures that animal welfare is compared amongst farms with similar production technologies. Farms are separated into different production types but we had sufficient data only for two of these production types: integrated pig producers and specialized slaughter pig producers.

We limited the scope of the analysis in this report to the “nulpunkt” animal welfare inspection, because the “nulpunkt” inspection was based on randomly sampled farms. Furthermore, we found that the data from the animal welfare control were not sufficiently similar to the data from the “nulpunkt” inspection.

The registrations of the economic and animal welfare data used in this report are based on two different approaches. The economic data is accountancy data and is therefore an aggregate of the economic transactions during the year 2011. The animal welfare data is measured at a single point in time during the fall of 2011. Therefore it does not represent the level of animal welfare during the year. During the inspection a farmer could be unlucky and have a violation noted despite it being a one-time event. This would not represent his general level of animal welfare, but the opposite scenario could also be the case. Furthermore, the checklist scheme is mostly constructed of environment-based indicators, which are consistent over time and easy to check. It is therefore less likely to get registered for an “undeserved” violation. Besides, it is justifiable to assume that for the entire dataset both lucky and unlucky events cancel out. Therefore it is argued that the data represent a good proxy of animal welfare at the investigated farms.

10. Conclusion and Perspectives

In this report we have studied the empirical relationships between animal welfare and the economic outcome of Danish pig producers.

We use data from the Danish animal welfare inspection to construct indicators of animal welfare. Based on a literature review it was concluded that a multidimensional indicator is best suited to assess animal welfare. Several indicators of animal welfare are used in the analysis, but it was found that the total number of violations of the animal welfare legislation comes closest to the ideal of a multidimensional indicator.

Two data sets on animal welfare inspection were initially taken into consideration for the economic analysis: the randomly sampled "nulpunkt" data and the risk-based sampled welfare control data. It is not surprising that statistical tests showed that the datasets are different and should be considered separately. However, it is surprising that integrated pig producers in the "nulpunkt" data more often and more severely violate the animal welfare regulations than integrated pig producers in the welfare control data. This could indicate that the "nulpunkt" inspection was stricter than the regular welfare control inspections (see section 3.6 and Forkman 2010) and/or it could indicate that the risk-based sampled welfare control data predominantly included integrated pig producers with a lower risk of violating the animal welfare regulations than average integrated pig producers. The underlying reasons to this would be worth considering for the employees managing the animal welfare inspection in Denmark. We only used the "nulpunkt" data in the economic analysis, because it is a random sample of Danish pig producers.

The results of our analysis suggest that the size of a farm and the age and experience of the farmer are generally not correlated with animal welfare. We did not find a clear relationship between animal welfare management and medicine and veterinary costs (when taking other factors into account). Our results show that integrated pig producers with good animal welfare have higher gross margins compared to farms with bad animal welfare but we did not find this relationship for specialized slaughter pig producers. This could indicate that farms with piglet production (mainly integrated pig producers) have larger economic incentives for providing good animal welfare than farms without piglet production (mainly specialized slaughter pig producers).In contrast, we found that good animal welfare was positively related to high technical efficiency for all production types. Anyway, based on our entire analysis, we suggest that the relationship between animal welfare and the economic outcome of pig producers should be interpreted within the context of the production type.

The results of this report show that there is in general a positive but weak relationship between animal welfare and the economic success of pig producers. This suggests that farmers who have better control of compliance with animal welfare regulations also perform economically better and are more efficient in the production. However, based on the analyses provided in this report, we cannot conclude on the causal relationship between animal welfare and economic outcome. The investigation of the causal relationship between animal welfare, economic outcome and other relevant factors, requires more detailed analyses based on additional and more detailed data.

However, although our findings about the relationship between animal welfare and the economic success of Danish pig producers are rather weak, they still can contribute to the discussion of the animal welfare legislation in Denmark. According to the results of our analyses, farmers who maintain a higher level of compliance with animal welfare regulations are not worse off than farmers who violate animal welfare regulations. This finding could be a valuable input in the political discussions on the animal welfare legislation, but the finding’s limitations should be stressed, because the causal relationship is not yet investigated. Therefore further studies are needed on this topic.

References

Agresti, A. (1990). Categorical data analysis. New York, Wiley-Interscience.

Ahmadi, B. V., Stott, A. W., Baxter, E. M., Lawrence, A. B. and Edwards, S. A. (2011). "Animal welfare and economic optimisation of farrowing systems. (Special Issue: Knowing animals.)." Animal Welfare 20(1): 57-67.

Aigner, D., Lovell, C. A. K. and Schmidt, P. (1977). "Formulation and estimation of stochastic frontier production function models." Journal of Econometrics 6(1): 21-37.

Anneberg, I. (2013). Actions of and interactions between authorities and livestock farmers - in relation to animal welfare, Århus Universitet.

Anneberg, I., Vaarst, M. and Sørensen, J. T. (2012). "The experience of animal welfare inspections as perceived by Danish livestock farmers: A qualitative research approach." Livestock Science 147(1–3): 49-58.

Arey, D. S. and Franklin, M. F. (1995). "Effects of straw and unfamiliarity on fighting between newly mixed growing pigs." Applied Animal Behaviour Science 45(1–2): 23-30.

Barnes, A. P., Rutherford, K. M. D., Langford, F. M. and Haskell, M. J. (2011). "The effect of lameness prevalence on technical efficiency at the dairy farm level: An adjusted data envelopment analysis approach." Journal of Dairy Science 94(11): 5449-5457.

Battese, G. E. and Coelli, T. J. (1995). "A model for technical inefficiency effects in a stochastic frontier production function for panel data." Empirical Economics 20(2): 325-332.

Beattie, V. E., Walker, N. and Sneddon, I. A. (1995). "Effects of Environmental Enrichment on Behaviour and Productivity of Growing Pigs." Animal Welfare 4(3): 207-220.

Bogetoft, P. and Otto, L. (2010). Benchmarking with DEA, SFA, and R.

Bornett, H. L. I., Guy, J. H. and Cain, P. J. (2003). "Impact of Animal Welfare on Costs and Viability of Pig Production in the UK." Journal of Agricultural and Environmental Ethics 16(2): 163-186.

Botreau, R., Bonde, M., Butterworth, A., Perny, P., Bracke, M. B., Capdeville, J. and Veissier, I. (2007a). "Aggregation of measures to produce an overall assessment of animal welfare. Part 1: a review of existing methods." Animal 1(8): 1179-1187.

Botreau, R., Bracke, M. B. M., Perny, P., Buttherworth, A., Capdeville, J., Reenen, C. G. v. and Veissier, I. (2007b). "Aggregation of measures to produce an overall assesment of animal welfare. Part 2: analysis of constraints." Animal 1: 1188-1197.

Broom, D. M. (1988). "The scientific assessment of animal welfare." Applied Animal Behaviour Science 20(1–2): 5-19.

Broom, D. M. (1991). "Animal welfare: concepts and measurement." Journal of Animal Science 69(10): 4167-4175.

Broom, D. M. (2008). Welfare Concepts. Welfare of Pigs. L. Faucitano and A. L. Schaefer, Waageningen Academic Publishers: 15-32.

Christensen, T., Lawrence, A., Lund, M., Stott, A., Sand and e, P. (2012). "How can economists help to improve animal welfare?" Animal Welfare 21(Supplement 1): 1-10.

Coelli, T.J. (1995), Estimators and Hypothesis Tests for a Stochastic: A Monte Carlo Analysis, Journal of Productivity Analysis, 6, 247-268.

Coelli, T. and Henningsen, A. (2012). frontier: Stochastic Frontier Analysis.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J. and Battese, G. E. (2005). An introduction to efficiency and productivity analysis. New York, NY, United States, Springer.

Curtis, S. E. (2007). "Commentary: Performance Indicates Animal State of Being: A Cinderella Axiom?" The Professional Animal Scientist 23(6): 573-583.

Danmarks Statistik (2013). Svinebestanden opgjort på kvartaler efter type.

Dawkins, M. S. (1983). "Battery hens name their price: Consumer demand theory and the measurement of ethological 'needs'." Animal Behaviour 31(4): 1195-1205.

Day, J. E. L., Burfoot, A., Docking, C. M., Whittaker, X., Spoolder, H. A. M. and Edwards, S. A. (2002). "The effects of prior experience of straw and the level of straw provision on the behaviour of growing pigs." Applied Animal Behaviour Science 76(3): 189-202.

Den Ouden, M., Huirne, R. B. M., Dijkhuizen, A. A. and Van Beek, P. (1997). "Economic optimization of pork production-marketing chains. II. Modelling outcome." Livestock Production Science 48(1): 39-50.

Department of Large Animal Sciences (2012). Nulpunktsundersøgelse af overholdelse af lovgivningen for dyrevelfærd i svinebesætninger, Faculty of Health and Medical Sciences, University of Copenhagen: 1-58.

Duncan, I. J. and Petherick, J. C. (1991). "The implications of cognitive processes for animal welfare." Journal of Animal Science 69(12): 5017-5022.

Dyrenes Beskyttelse. (2013). "Anbefalet af Dyrenes Beskyttelse." Retrieved 01.04, 2013, from http://www.dyrenesbeskyttelse.dk/anbefalet-af-dyrenes-beskyttelse.

Ekkel, E. D., Spoolder, H. A. M., Hulsegge, I. and Hopster, H. (2003). "Lying characteristics as determinants for space requirements in pigs." Applied Animal Behaviour Science 80(1): 19-30.

Emerson, J. D. and Moses, L. E. (1985). "A Note on the Wilcoxon-Mann-Whitney Test for 2 x k Ordered Tables." Biometrics 41(1): 303-309.

Forkman, B. (2010). Velfærdsvurdering og velfærdskontrol. Dyrevelfærd i Danmark, The Danish Veterinary and Food Administration. Dyrevelfærd i Danmark 2010: 26-31.

Gjerris, M. (2012). Er vi verdensmestre i dyrevelfærd?, Berlingske. 2012.

Greene, W. H. (2008). Econometric Analysis, Pearson Education.

Guy, J. H., Cain, P. J., Seddon, Y. M., Baxter, E. M. and Edwards, S. A. (2012). "Economic evaluation of high welfare indoor farrowing systems for pigs." Animal Welfare 21(Supplement 1): 19-24.

Hansen, H. O. and Andersen, J. M. (2013). Danish Agricultutal Economy 2012, Department of Food and Resource Economics, University of Copenhagen.

Huynh, T. T. T., Aarnink, A. J. A., Gerrits, W. J. J., Heetkamp, M. J. H., Canh, T. T., Spoolder, H. A. M., Kemp, B. and Verstegen, M. W. A. (2005). "Thermal behaviour of growing pigs in response to high temperature and humidity." Applied Animal Behaviour Science 91(1–2): 1-16.

Jensen, T. B., Baadsgaard, N. P., Houe, H., Toft, N. and Østergaard, S., (2008). "The association between disease and profitability in individual finishing boars at a test station." Livestock Science 117(1): 101-108.

Jensen, T., Kold Nielsen, C., Vinther, J. and D'Eath, R. B. (2012a). "The effect of space allowance for finishing pigs on productivity and pen hygiene." Livestock Science 149(1–2): 33-40.

Jensen, T. B., Kristensen, H. H. and Toft, N. (2012b). "Quantifying the impact of lameness on welfare and profitability of finisher pigs using expert opinions." Livestock Science 149(3): 209-214.

Keeling, L. J. (2005). “Healthy and Happy: Animal Welfare as an Integral Part of Sustainable Agriculture." AMBIO: A Journal of the Human Environment 34(4): 316-319.

Ladewig, J. (2005). "Of mice and men: Improved welfare through clinical ethology." Applied Animal Behaviour Science 92(3): 183-192.

Lagerkvist, C. J. and Hess, S. (2011). "A meta-analysis of consumer willingness to pay for farm animal welfare." European Review of Agricultural Economics 38(1): 55-78.

Lassen, J., Jensen, K. K. and Thorslund, C. (2012). Egenkontrol af dyrevelfærd, Department of Food and Resource Economics, University of Copenhagen.

Lawrence, A. B. (2009). Profitting from Animal Welfare: An Animal-based Perspective. The Oxford Farming Conference 2009: 11.

Lawson, L. G., Agger, J. F., Lund, M. and Coelli, T. (2004a). "Lameness, metabolic and digestive disorders, and technical efficiency in Danish dairy herds: a stochastic frontier production function approach." Livestock Production Science 91(1–2): 157-172.

Lawson, L. G., Bruun, J., Coelli, T., Agger, J. F. and Lund, M. (2004b). "Relationships of Efficiency to Reproductive Disorders in Danish Milk Production: A Stochastic Frontier Analysis." Journal of Dairy Science 87(1): 212-224.
Lebret, B., Massabie, P., Granier, R., Juin, H., Mourot, J. and Chevillon, P. (2002). "Influence of outdoor rearing and indoor temperature on growth performance, carcass, adipose tissue and muscle traits in pigs, and on the technological and eating quality of dry-cured hams." Meat Science 62(4): 447-455.
Lund, M., Otto, L. and Jacobsen, B. H. (2010). Økonomiske analyser for Justitsministeriets arbejdsgruppe for hold af svin. FOI Udredning 2010 / 19.
Lusk, J. L. and Norwood, F. B. (2011). "Animal Welfare Economics." Applied Economic Perspectives and Policy: 21.
Majewski, E., Malak-Rawlikowska, A., Gebska, M., Hamulczuk, M. and Harvey, D. R. (2012). Cost-effectiveness Assesment of Improving Animal Welfare Standards in European Agriculture. International Association of Agricultural Economists - Conference 2012. Foz do Iguaçu, Brazil: 22.
McInerney, J. (2004). Animal Welfare, Economics and Policy. London, UK.: 80.
Meeusen, W. and Broeck, J. v. D. (1977). "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error." International Economic Review 18(2): 435-444.
Mellor, D. J. and Stafford, K. J. (2004). "Animal welfare implications of neonatal mortality and morbidity in farm animals." The Veterinary Journal 168(2): 118-133.
Millet, S., Moons, C. P. H., Van Oeckel, M. J. and Janssens, G. P. J. (2005). "Welfare, performance and meat quality of fattening pigs in alternative housing and management systems: a review." Journal of the Science of Food and Agriculture 85(5): 709-719.
Ministry of Food Agriculture and Fisheries of Denmark (2011a). Den generelle instruks for kontrollen af dyrevelfærd. M. o. F. A. a. F. o. Denmark: 1-35.
Ministry of Food Agriculture and Fisheries of Denmark (2011b). Instruks for velfærdskontrol i svinebesætninger. M. o. F. A. a. F. o. Denmark: 1-62.
Ministry of Food Agriculture and Fisheries of Denmark (2013). Bekendtgørelse af dyreværnsloven. Danish Veterinary and Food Administration.
Munsterhjelm, C., Valros, A., Heinonen, M., Hälli, O. and Peltoniemi, O. A. T. (2006). "Welfare Index and Reproductive Performance in the Sow." Reproduction in Domestic Animals 41(6): 494-500.
Olsen, J. V. and Henningsen, A. (2011). "Investment Utilisation, Adjustment Costs, and Technical Efficiency in Danish Pig Farms." IFRO Working Paper(2011/13).
Ózsvári, L., Bíró, O. and Lakner, Z. (2012). "Role of veterinary management in increasing pig breeding efficiency: a methodological approach." Studies in Agricultural Economics (Budapest)(114): 10-15.
Pedersen, L. J., Berg, P., Jørgensen, E., Bonde, M. K., Herskin, M. S., Knage-Rasmussen, K. M., Kongsted, A. G., Lauridsen, C., Oksbjerg, N., Poulsen, H. D., Sorensen, D. A., Su, G., Sørensen, M. T., Theil, P. K., Thodberg, K. and Jensen, K. H. (2010). Pattegrisedødeligheden i DK - Muligheder for reduktion Pattegrisedødeligheden i Danmark. Husdyrbrug. P. L. Juul and J. K. Hjelholt, Aarhus University. 86: 1-80.
Politiken (2013a). EU truer Danmark i sag om svinevelfærd, Politiken. 2013.
Politiken (2013b). Landbruget: Vi er ikke så slemme som 'Borgen' viser, Politiken. 2013.
Rasmussen, S. (2010). "Scale efficiency in Danish agriculture: an input distance–function approach." European Review of Agricultural Economics 37(3): 335-367.
Rushen, J. (2003). "Changing concepts of farm animal welfare: bridging the gap between applied and basic research." Applied Animal Behaviour Science 81(3): 199-214.
Ruxton, G. D. (2006). "The unequal variance t-test is an underused alternative to Student's t-test and the Mann–Whitney U test." Behavioral Ecology 17(4): 688-690.
P. Sandøe (2010): Welfare. The encyclopedia of applied animal behavior & welfare. D. S. Mills, J. N. Marchant-Forde, P. D. McGreevy, D. B. Morton, C. J. Nicol, C. Gamborg, B. Gremmen, S. B. Christiansen & P. Sandøe (eds.). Wallingford, CAB International, pp. 642-643

Sandøe, P., Christensen, T., Forkman, B. and Lassen, J. (2012). "Definitions of and attitudes to animal welfare", Animal welfare in Denmark 2010, Danish Veterinary and Food Administration: 14-25

Scientific Veterinary Committee (1997). The Welfare on Intensively Kept Pigs, For the European Commission: 1-191.

Seibert, L. and Norwood, F. B. (2011). "Production Costs and Animal Welfare for Four Stylized Hog Production Systems." Journal of Applied Animal Welfare Science 14(1): 1-17.

Sinisalo, A., Niemi, J. K., Heinonen, M. and Valros, A. (2012). "Tail biting and production performance in fattening pigs." Livestock Science 143(2–3): 220-225.

Stott, A. W., Vosough Ahmadi, B., Dwyer, C. M., Kupiec, B., Morgan-Davies, C., Milne, C. E., Ringrose, S., Goddard, P., Phillips, K. and Waterhouse, A. (2012). "Interactions between profit and welfare on extensive sheep farms." Animal Welfare 21(Supplement 1): 57-64.

Tuyttens, F. A. M. (2005). "The importance of straw for pig and cattle welfare: A review." Applied Animal Behaviour Science 92(3): 261-282.

van der Fels-Klerx, H. J., Puister-Jansen, L. F., van Asselt, E. D. and Burgers, S. L. G. E. (2011). "Farm factors associated with the use of antibiotics in pig production." Journal of Animal Science 89(6): 1922-1929.

Verzani, J. (2004). Using R for introductory statistics, Chapman and Hall/CRC.

Wiepkema, P. R. and Koolhaas, J. M. (1993). "Stress and Animal Welfare." Animal Welfare 2(3): 195-218.

Winter, M., Fry, C. and Carruthers, S. P. (1998). "European agricultural policy and farm animal welfare." Food Policy 23(3–4): 305-323.

Wooldrige, J. (2009). Introductory Econometrics: A Modern Approach, South-Western College Pub.

Appendix

A. Statistical tests

This section provides a presentation and an overview of the statistical tests used in the report. In the description of the tests the focus is on the intuition of using the test, and not on mathematical and statistical properties.

A.1. Welch's Two Sample T-test

Welch's two sample t-test is also known as the unequal variance t-test (Ruxton 2006). The t-test is used to compare differences in group means. The Welch's two-sample t-test is comparable to the Student's t-test. It assumes normally distributed populations, and the t-distribution is used for hypothesis testing. Contrary to the Student's t-test, Welch's two sample t-test does not assume equal sample variances of the groups being compared.

The null hypothesis: the two population means are equal.

We used Welch's t-test to test for differences in e.g. gross margin per pig unit for farms with or without a violation.

A.2. ANOVA

Analysis of variance (ANOVA) is used to test for differences in means for 2 or more groups (Verzani 2004). The test assumes independent and normal distributed samples, and equal sample variances. The F-statistic is used to evaluate the differences between groups. The null hypothesis is that all group means are the same. The alternative hypothesis is that not all means are the same. If the null hypothesis is rejected, because there is a difference in means, then Tukey's pairwise comparison test can be used to test for differences between groups. Tukey's test compares sample means simultaneously, unlike the ordinary t-test.

This test is used to test for differences in e.g. gross margin per pig unit for the most severe violations.

7.2.6. A.3. $\chi 2$ Test

Pearson's χ^2 test of independence is used to test for differences between categorical variables, where the categorical variables have two or more possible values (Agresti 1990). The null hypothesis is that the relative proportions of one variable are independent of the other variable. The alternative hypothesis is that the proportions of one variable are dependent on the other variable. The distribution of the chi-square test statistic under the null hypothesis is approximately the same as the theoretical chi-square distribution.

This test is used e.g. when testing whether there is a difference in the distribution of farms with or without violations between the “nulpunkt” data and the welfare control data.

A.4. Mann-Whitney U Test

The Mann-Whitney U test is used for ordered categorical data (Emerson and Moses 1985). It is a non-parametric test, which means that no prior assumption on distributions is made, but for sample sizes greater than 20 it follows the z-distribution. It is used to test whether two samples are drawn from the same population. The test is performed by combining the two samples into one dataset and then ranking the observations. For each sample the number of observations ranked higher than observations from the other sample is counted. These results are compared in the test. The null hypothesis: Two samples, x and y, have identical distributions and are from the same population. The alternative hypothesis: x and y do not have identical distributions, and are not from the same population.

This test is used e.g. to compare the distribution of the total number of violations between the “nulpunkt” data and the welfare control data.

A.5. Pearson’s Correlation Coefficient

Pearson’s product-moment correlation coefficient can be used to test the association between two numeric variables from the same sample (Wooldrige 2009). The significance of this correlation can be tested using a two-tailed t-test. The null hypothesis is that correlation equals zero. The alternative hypothesis is that correlation is different from zero.

The correlation test is used e.g. to check for association between gross margin per pig unit and the total number of violations.

A.6. Likelihood Ratio Test.

The likelihood ratio test compares the fit of two models by calculating The likelihood ratio (Greene 2008). The likelihood ratio expresses how many more times likely the data are under one model than the other. One model should be a special case of the other, i.e. a restricted model should be nested within an unrestricted model. The unrestricted model has more parameters, and will therefore fit the data as least as well as the restricted model. If the log likelihood values are similar for the restricted and unrestricted values, then the restricted model most likely fits the data better. The likelihood ratio test statistic has asymptotically mixed χ^2 distribution (Coelli, 1995).

The likelihood ratio test is used e.g. to compare the fit of the estimated stochastic output distance function against the nested Ordinary Least Square model i.e. the restricted model without inefficiency.

B. Summary of the results of descriptive analysis

Table B.1 shows the results from testing the relationship between the 8socio-economic variables and 5 indicators of animal welfare for integrated pig producers. The significance level of the test is given along with the direction of the result. If the test result is insignificant "None" is reported.

Table B.1. Test results for integrated pig producers

	Total number of violations *(correlation?)*	**Most severe violation** *(significant difference?)*	**AnyViolation** *(significant difference?)*	**AnyRooting** *(significant difference?)*	**AnySick** *(significant difference?)*
Pig units	None	None	None	None	None
Gross margin (GM)	10 %-level. Decreasing GM if violations	10 %-level. There is a difference.	10 %-level. Lower GM if violation	5 %-level. Lower GM if violation	None
Medicine and veterinary costs	None	None	10 %-level. Lower costs if violation	10 %-level. Lower costs if violation	5 %-level. Lower costs if violation
Revenue	None	10 %-level. There is a difference.	None	1 %-level. Lower revenue if violation	None
Feed costs	None	None	None	None	None
Other costs	None	None	None	None	None
Age	None	None	None	None	None
Experience	None	None	None	None	None

Table B.2 shows the results from testing the relationship between 8socio-economic variables and 5 indicators of animal welfare for specialized slaughter pig producers. The significance level of the test is given along with the direction of the result. If the test result is insignificant "None" is reported in the cell.

Table B.2. Test results for specialized slaughter pig producers

	Total number of violations *(correlation?)*	**Most severe violation** *(significant difference?)*	**AnyViolation** *(significant difference?)*	**AnyRooting** *(significant difference?)*	**AnySick** *(significant difference?)*
Pig units	None	None	None	None	None
Gross margin	None	None	None	None	None
Medicine and veterinary costs	None	10 %-level. There is a difference	10 %-level. Higher costs if violation	None	10 %-level. Higher costs if violation
Revenue	<1 %-level. Increasing revenue if violations	None	10 %-level. Higher revenue if violation	None	None
Feed costs	None	None	None	None	None
Other costs	10 %-level. Higher other costs if violations	None	10 %-level. Higher other costs if violation	None	10 %-level. Higher other costs if violation
Age	None	None	None	None	None
Experience	None	None	None	None	10 %-level. Less experienced if violation.